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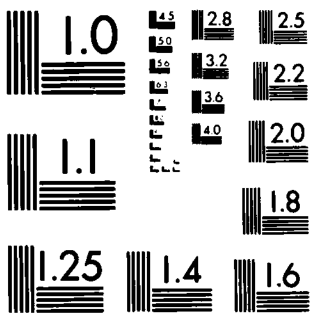

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PRELIMINARY COST ESTIMATING FOR
HIGHWAY CONSTRUCTION PROJECTS

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PRELIMINARY COST ESTIMATING FOR

HIGHWAY CONSTRUCTION PROJECTS

Albert Frank Kaminsky, Jr.

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

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August 27, 1986

PRELIMINARY COST ESTIMATING FOR

HIGHWAY CONSTRUCTION PROJECTS

Albert Frank Kaminsky, Jr.

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VITA

Albert Frank Kaminsky, Jr., son of Albert and Margaret (Tokos) Kaminsky, was born on December 15, 1951, in Johnson City, New York. He attended Binghamton North High School, Binghamton, New York, and graduated from there in June 1969. In July, 1969, he entered the United States Military Academy at West Point, New York. On June 6, 1973, he graduated with a Bachelor of Science Degree. Upon graduation, he was commissioned as a Second Lieutenant Infantry in the Regular Army. He has served overseas in Alaska, the Panama Canal Zone, Israel, Egypt, and the Carribean. He is presently serving on active duty and holds the rank of Major. Major Kaminsky has served in a wide variety of military positions and has commanded both Infantry and Engineer Companies. He entered Auburn University for graduate studies in Construction Engineering Management in January, 1985. He is married to Carol (Mondolfi) Kaminsky and has one daughter, Ariane Sarah.

THESIS ABSTRACT

PRELIMINARY COST ESTIMATING FOR

HIGHWAY CONSTRUCTION PROJECTS

Albert Frank Kaminsky, Jr.

Master of Science, August 27, 1986
(B.S., United States Military Academy, 1973)

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to three distinctly different types of construction projects examined in this research confirm its usefulness. The preliminary cost estimating procedure developed for the AHD is workable and can be applied to a wide range of highway construction and maintenance projects.

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I. INTRODUCTION

The process of decision making for the design and execution of highway construction projects demands the ability to forecast the cost of these projects with reasonable accuracy. In terms of allocating resources or budgeting, the estimation of future project costs is one of the more significant and complicated problems faced by all levels of government. Many decisions in the process of design, resource allocation and construction are dependent on a reliable determination of future project cost. It is a well known fact in the construction industry that the time span from the conceptual design of a construction project to the actual performance can often be several years.

Research Objective

The primary objective of the research described herein was to develop a method of estimating future highway maintenance and construction costs. The requirement to have an accurate estimate of future project costs stems from the annual budgeting process within the State of Alabama and the lengthy delay in budget implementation. This research is a continuation of previous research conducted by Mr. Tom Garrett and Dr. Lansford C. Bell, of the Auburn University

Department of Civil Engineering, for the State of Alabama Highway Department (AHD) (8). In their research, Garrett and Bell developed a linear regression analysis procedure to predict the unit price for a material used in a construction project bid submission. This procedure involved the use of actual bid data from previous years. In the analysis and development of their model, Garrett and Bell concluded that for most material items the unit price was principally affected by three variables. The most important variable was material quantity. The other variables were the type of project or category and the geographical location within the state.

A standard regression analysis equation was developed which predicts unit cost of an individual bid pay item as a function of quantity, geographical location and project type. This research was conducted using actual highway department cost data, the Auburn University mainframe computer and the program Statistical Analysis System (SAS) (8).

The State of Alabama Highway Department is at present implementing the multiple regression analysis equations developed at Auburn University. This regression analysis provides the AHD with the means to review unit price data submitted by contractors. This procedure has thus far

accurately predicted project costs that closely approximate the successful bid of contractors on several different projects.

As a follow-on to the recently completed research the AHD desired to develop a preliminary cost estimating procedure that can be applied before engineering estimates of material quantities are available. The primary motivation for this requirement was to provide a project cost for incorporation into a future annual budget.

Methodology

In the initial phase of the research investigation very little information was found on the subject of estimating future costs for road construction. The field of estimating is broad and often unstructured. The methods used in estimating project cost are as diverse as each construction company or governmental agency and are often the product of experience and what works best for the estimator. Owners, in this case the AHD, and contractors take a distinctly different approach to estimating the cost of highway related construction projects. The contractor formulates his project cost estimate based on such factors as labor costs, labor crew productivity, material costs, equipment costs, overhead, and contingencies. On the other hand, state highway departments typically estimate construction costs using historical bid data associated with previously executed construction projects.

Highway related projects are always bid on a unit price basis with some items being bid as a lump sum. The project is organized into a number of discrete work and material items. Lump sum prices are provided for each work item and unit prices for each material item. The bid, or project cost, is determined through a multiplication process where the cost of an item is the product of unit price times quantity. A contractor arrives at a unit price or lump sum price for each material or work item only after evaluating a wide range of factors. The AHD on the other hand can determine an estimated unit price through a multiple regression analysis procedure and comparison to historical bid data for similar projects.

A literature review conducted by the writer revealed only one instance where similar cost estimating research was conducted. The State of Florida Department of Transportation (FDOT) is required to prepare a 5 year budget plan (9). Recognizing the need to find a technique which would enable them to predict changes in costs several years in the future, a model to be used in the budgeting process was developed. The model for "Long Range Forecasting of Highway Construction Costs" was based on multiple regression analysis involving such cost factors as material cost, equipment rates, labor rates and the effects of bidding volume (9). The approach taken by the researchers for FDOT

was found to be too complex to meet the specific need of the State of Alabama Highway Department.

As a result of the lack of future cost estimating information it has become necessary to develop a procedure for estimating future costs for road construction within the State of Alabama. The initial request to the AHD for information resulted in release of actual project bid sheets for 174 projects. These projects were executed from October 1, 1983 through January 30, 1985. These bid sheets provided a wealth of information ranging from project type to material quantity and unit cost. The decision was made to develop either a manual cost estimating method or computer algorithm to assist the AHD. The amount of data to be analyzed indicated that a computer database would be necessary.

The AHD proposed certain guidelines to keep the proposed estimating procedure as simple and usable as possible. One of the guidelines was to avoid the use of a mainframe computer. By meeting these guidelines it was felt that any method developed could be used by the AHD division and district offices.

The database was designed using a microcomputer and commercially available software package. By creating a computer database, easy access to data of interest could be almost instantaneous. In addition, it eliminated the need to maintain large amounts of paper files. With the bid data

in the computer database, the project information could be examined in detail and the direction of the research narrowed.

Through extensive database file indexing and examination of trends in the data, it was found that one-third or less of the construction pay items comprised the major portion of the bid. This major portion was often 90 percent or more of the total project cost. This relationship was found to be true for three distinctly different categories of construction projects. If the quantity of these dominant materials could be estimated with reasonable accuracy for a proposed project then an adjustment could be made to known values of a typical project and the cost estimated.

This analysis of cost data, material quantity and project length resulted in the construction of a graph that would provide a base cost per unit of measure for a proposed project length. Subsequently, this base cost could be adjusted for anticipated variation in dominant material requirements.

Once the database has been established and the project category analyzed, the cost estimation procedure developed requires as input only an estimate of project length and an approximate determination of dominant material quantities. For the proposed project, a base cost per unit of measure (mile or foot) is first determined. The estimator would

then adjust this base cost for specific variations in dominant material quantities by either increasing or decreasing the base cost by some percentage. The proposed project total cost estimate would be the product of the length and adjusted base cost per unit of measure.

The capabilities of the microcomputer and database software package used in developing this procedure will be discussed in Chapter III. The specifics concerning the development of this construction cost estimating procedure for three major construction project categories will be discussed in detail in Chapters IV, V, and VI.

II. MAINTENANCE AND MANAGEMENT RESPONSIBILITIES OF THE STATE OF ALABAMA HIGHWAY DEPARTMENT

Background and Organization

The State of Alabama Highway Department was created by the State Legislature with the mission of building and maintaining the state highways of Alabama. The Chief Executive Officer of the Highway Department is the Highway Director. He is appointed by the Governor and serves in the office at the pleasure of the Governor. The Director, as Chief Executive Officer, is authorized to enter into all contracts that are necessary to carry on highway construction and maintenance within the state. Personnel necessary to carry out the Department's operations are appointed by the Highway Director.

The Alabama Highway Department is organized into 12 bureaus, 7 headquarters divisions, and 9 operational divisions. To perform its mission the AHD employed approximately 4050 people in 155 different job classifications during the 1984 fiscal year. During the same fiscal year the average biweekly payroll was $2,676,268.00 (17).

Maintenance Responsibilities

The maintenance and construction responsibilities of the AHD are demanding and extensive. The road network contains 11,085 miles of state highways which includes 906.5 miles of the Interstate Highway System. The Maintenance Bureau, in addition to maintaining the state road network, maintains 200 miles of roads and streets at state facilities as well as 15,540 bridges (17).

The major sources of income for the AHD are Federal Aid, Gasoline and Motor Fuel Tax, and Motor Vehicle and Motor Carrier Tax. During the 1984 fiscal year receipts totaled $597,169,066.00. During the same period expenditures totaled $485,105,668.00 (17). Based on the amount of money spent by the AHD on road construction and repair, it is apparent that the road network is a major contributor to the Alabama economy.

Alabama Highway Department Budget

The current policy of the AHD is to limit expenditures to anticipated income in a fiscal year. Therefore, road construction and maintenance is limited to those projects that can be accomplished with budgeted funds. In 1971, the AHD was placed on a legislative budget requiring legislative approval of funding.

The budgeting system followed by the State of Alabama is similar to that of other several states and the Federal Government. The State of Alabama operates on a fiscal year

which begins on 1 October and ends on 30 September of the following year. The budget for each fiscal year is developed 15 to 18 months prior to the beginning of the fiscal year.

The development of the annual budget is a time consuming and difficult process. In most cases, needs usually exceed resources and a prioritizing of work to be performed within funding guidelines is required to take place. Accurately determining needs, estimating future project costs, and programming expenditures is of the utmost importance. It is incumbent upon responsible officials to exercise great discretion in formulating budgets. The desire to balance the federal budget could lead to the elimination of many traditional sources of income that state governments have become accustomed.

As stated above, the AHD budget is an annual requirement. In the fall of the year preceding the beginning of the fiscal year the AHD budget is submitted to the State Fiscal Officer for incorporation into the Governor's budget submission to the legislature. The legislature reviews the budget request in the spring of the year and approves a budget prior to adjournment in the late spring.

Although the budget process described is an overview and has eliminated the direct interaction between the executive and legislative branches of government, it is

clearly evident that the budgeting process for the AHD often begins two years prior to the beginning of the fiscal year. It follows that project planning and cost estimation may be executed three to four years in advance of project execution. The need for a procedure within the AHD to accurately estimate the cost of future construction projects is apparent.

III. TOOLS OF COST ESTIMATING

Evolution of Microcomputers

The estimation of project cost by computer is not a new concept. However, the introduction of the low cost microcomputer or personal computer (PC) is a new technology which has brought computing power to both businesses and levels of government which previously could not afford it. By utilizing a microcomputer, one person can now do more per unit of time than was previously possible, as well as perform tasks which previously may have been too difficult to perform alone (12). The complex and often repetitious activities involved in cost estimating make the microcomputer a prime candidate for use in cost estimating.

The microcomputer field was already a multimillion-dollar business when the International Business Machines Corporation (IBM) introduced its first microcomputer, the IBM PC, in 1981. With the introduction of the generation of microcomputers such as the IBM PC-AT and the AT&T 7300, the user has much of the capabilities of mainframe computer systems of less than a decade ago.

Capabilities of the Microcomputer

The advantages of using a microcomputer for cost estimating are numerous.. As previously noted, the microcomputer has the primary storage capacities of mainframes of ten years ago. The cost estimator has the computing resources available at his/her fingertips and does not have to compete with others for its use. Interactive capability of the microcomputer is extremely useful in developing answers to 'what-if' situations. The attractiveness of a microcomputer over a mainframe computer is enhanced with its dedicated use to the cost estimating function and the immediate response that the estimator enjoys with the interactive software programs. The considerable time delays associated with the use of a mainframe computer is eliminated. Microcomputers have a relatively lower acquisition cost when compared to a minicomputer or mainframe computer. Improved accuracy is provided by a computerized estimating system over a manual system. The chances of making mathematical errors are reduced and if errors are made they are more easily detected and corrected. Microcomputers take advantage of user friendly software packages and require a much lower level of expertise to perform a function when compared to both a minicomputer and mainframe computer.

In order to best utilize the new technology, the cost estimator must make a personal commitment to develop the

skills necessary to use the microcomputer properly and effectively. The large number of microcomputers in use (3.2 million in 1984) attest to their ability to assist users in job performance (7).

The development of cost estimating, database management, and spreadsheet software for microcomputers has been dependent upon the development of the microprocessor. Computer processing speed is the rate at which the computer executes instructions. This rate is actually how fast the computer can manipulate numbers or produce text documents. The microprocessor of a microcomputer is the brain which interprets and executes instructions which are sent to it by the user. The speed at which the microcomputer executes applications is dependent upon the microprocessor's internal clock which instructs the microprocessor when to execute instructions (14). During processing of a program instruction, there are two cycles which actually occur. These cycles are the instruction and execution cycles. They are coordinated by the number of electrical pulses generated by the internal clock measured in megahertz (MHz). The speed at which processing is executed is directly related to the microprocessor's clock speed (15). The faster the microprocessor's clock, the faster the processing is executed.

To realize the relative power of database management software packages, one must first understand the generations

of microprocessors and the microcomputers associated with them. The microcomputer revolution began with the introduction of the ALTAIR 8800, introduced in 1974. The first machines used 8-bit microprocessors, which moved and processed data in 8-bit chunks. The dominant machines which used the first generation of microprocessors, popular in the late 1970's and early 1980's, were the TRS-80 series of Tandy Corporation and the Apple-II series from Apple Computer, Inc. Many of the microcomputers using the first generation of microprocessors were machines limited to 64 k-bytes of Random Access Memory (RAM).

The second generation of microprocessors were introduced in the early 1980's, and were based on the 16-bit microprocessor. Many of the microcomputers using second generation microprocessors started with 64 k-bytes of RAM, but were expandable, some up to 640 k-bytes of RAM. In addition, many used the Intel 8088 16-bit microprocessor, which was actually a 8/16 bit microprocessor. The microprocessor operates like a fast 8-bit microprocessor, and moves only 8 bits at a time. However, it processes data 16-bits at a time. In addition, these microprocessors contained a much faster internal clock (4.77 MHz), than the previous first generation microprocessors (16). The faster clock of the second generation microprocessor, when coupled to the larger processing capabilities of the processor, increased processing speed. The most popular microcomputer

utilizing a second generation microprocessor is the IBM Personal Computer.

The third generation of microprocessor are true 16-bit microprocessors. The microprocessors move data in 16-bit chunks, with some microprocessors in the family processing data 32-bits at a time.

Microcomputer Hardware

In the development of the cost estimating procedure for the AHD, the IBM PC-AT microcomputer was selected because it has certain desirable attributes not available on most standard microcomputers. The IBM PC-AT, introduced in August, 1984, is based on the Intel 80286 microprocessor. The Intel 80286 microprocessor uses a 16-bit data path and a 24-bit processor with a 6 megahertz clock (1).

Several other features of the IBM PC-AT distinguish it as a microcomputer and new standard for desk top computers. The IBM PC-AT system may be configured with up to 640 k-bytes of RAM addressed in the real address mode of the Disk Operating System (DOS) and up to 3-megabytes in the virtual address mode.

Hardware configuration options for the IBM PC-AT include a high capacity disk drive that stores 1.2 megabytes of data, as well as the standard 360 k-byte drive. A variety of fixed disk drives with storage capacities of up to 60 megabytes are now available.

The advanced technology of the IBM PC-AT and the development of an advanced operating system make this computer the front runner in the development of multi-user systems linking input terminals, other microcomputers, and mainframe computer systems.

Microcomputer Software

The rapid advance in microprocessor technology has encouraged the development of a wide variety of software packages with application in cost estimating. The three categories of software that are most appropriate for use in cost estimating are spreadsheet programs, application programs and data base management programs (DBMS). Each category of software provides the cost estimator with unique capabilities to perform cost estimating. However, as powerful as these software programs are they are not all encompassing and have limitations to their application.

The first category of software to be discussed are spreadsheet software packages. The most common spreadsheet software package in use today is LOTUS 1-2-3, a product of the Lotus Development Corporation. The major characteristic of spreadsheet software is that it provides the cost estimator with a large tabular workspace of coordinate locations. Number, labels and formulas are entered into the coordinate locations by moving a lighted box or cursor around the spreadsheet workspace with the keyboard cursor or arrow keys. Almost any engineering or business problem that

can be solved in a tabular format can be adapted to a spreadsheet solution. The real power of spreadsheet software lies in the ability to repeatedly execute problem solutions using different sets of input data. A spreadsheet is the ideal method of conducting a sensitivity or 'what-if' analysis. Spreadsheet software also has the additional capabilities of graphical presentation. A limitation of spreadsheet software is that it must be compatible with the hardware or computer that is being used. Another limitation is that spreadsheet software may not be adaptable to every situation faced by the cost estimator.

The second category of software to be discussed is commonly referred to as application software. An application program is a program written in a programming language to perform a specific end user task. Typical uses of application software include accounting, inventory control and engineering design. A major advantage of application software for small computers is its availability as a preprogrammed package for immediate use. A major disadvantage of using an application is its inflexibility and inability to be adapted to changing requirements. Other disadvantages include hardware compatibility, end user technical support and the quality of documentation.

The third category of software to be discussed is data base management software (DBMS). Database management software is used to manipulate large collections of data.

Dedicated database management programs such as dBASE III are designed for creating large databases and performing complex arithmetic, sorting and indexing operations. Database management software also provides the user with the capability of on line access and a fast response to users with special information needs. Database management software is ideally suited for comparing data and determining interrelationships between data fields. The disadvantages of database management software are relatively few, and in the long run certainly outweighed by the advantages. One disadvantage is that database management systems software is complex. Therefore, DBMS requires a higher level of expertise and dedication to learning the software package. Because of the large amount of data associated with the preliminary cost estimating procedure a database management systems software package was determined to be the software of choice.

Database Management Software in Cost Estimating

The database management software selected for use in the development of a future cost estimating procedure for the AHD was dBASE III, a product of Ashton-Tate, Inc. The software package dBASE III can best be described as both a database management system (DBMS) and a programming language (5).

The software package dBASE III was specifically designed to run on the IBM PC-AT to take advantage of the

expanded capabilities of the Intel 80286 microprocessor (5). In order to more fully understand the capabilities of dBASE III and the IBM PC-AT microcomputer several terms must be defined and both hardware capabilities, software capabilities, and the interrelationship between software and hardware discussed.

A database is a collection of useful information organized in a specific manner that is shared and used for multiple purposes. The term Data Base Management System (DBMS) is defined as a systematic way to organize and manage a database in a large computer system (5). A database may be composed of one or more data base files. A file is a set of related records treated as a unit (16). A file is composed of data elements organized into records and fields. A field is the smallest logical data entry (16). A field is a group of related characters treated as a single element. A simple example of a field in a project bid is material quantity. A record is a collection of related fields that is treated as a single unit. A database file is organized in matrix form. Records are represented as rows within the matrix. Fields are represented as individual columns within the matrix encompassing one data entity. Because of the introduction of powerful microcomputers such as the IBM PC-AT and computer programs like dBASE III, database management on microcomputers is now a major application of computer technology in the private and public sector.

dBASE III in Data Management

As a database management tool, dBASE III has two processing modes. In an interactive mode, the operator can create and manipulate data files by typing the commands directly from the keyboard. Because the computer responds instantly, the operator can monitor the input and output processes with easy to use commands. The other processing mode is batch processing, which represents one of the most important utilities provided by dBASE III. Batch processing offers all the power and flexibility necessary for designing an integrated menu driven database management system.

In dBASE III a data file represents the memory space reserved for holding information in memory. The limitations on a dBASE III data file are:

File Limits (maximum size)	
Number of Records/File	1 billion
Record Size (bytes)	4000 bytes in .dbf file
Number of Fields/Record	128
Memory Variables	256
Digits Allowed	15 digits . 9 digits (24 total)
Open Data Files Allowed	10

In developing the preliminary cost estimating procedure for the AHD, historical project bid data were used. A typical project bid is shown in Table 1. In converting the information contained in a project bid to a database file an abbreviated description of bid data elements was used to

describe the field names in the database file structure. The following list describes the abbreviated field names in more detail:

Field	Field Name	Bid Data Entry
1	PROJ_NO	Project Number
2	LENGTH	Project Length
3	ZONE	Alabama Geographic Zone
4	BID_DATE	Bid Opening Date
5	ITEM_NO	Pay Item Number
6	QUANTITY	Material Quantity
7	DESCRIPT	Pay Item Description
8	ITEM_AMT	Extended Amount
9	COST	Extended Amount / Project Length

A typical database file structure is shown in Table 2, which is the structure used for an actual file created for the AHD database.

In the development of the database for the AHD, a relational data base was used. That is, the database was organized as a two dimensional table consisting of rows and columns (5). The advantages of a relational database are that it provides an effective means for maintaining and manipulating large amounts of information. Some useful functions that can be performed on a relational database are:

- Maintaining and updating the contents of a database;
- Locating and retrieving data that meets a given set of specifications; and,
- Sorting or rearranging a set of data items into a predetermined sequence or order (5).

Table 1

Example low bid:
Maintenance and Resurfacing Category project #10

PROJECT: 24-006-005-022-402
COUNTY: DALLAS COUNTY-047
LENGTH: 12.950 Miles Resurfacing
LOCATION: On AL-#22 from MP 25.100 to MP 38.050 (ZONE 3)
BIDS OPENED: September 28, 1984

ITEM NO.	QUANTITY	ITEM	UNIT PRICE	EXTENDED AMOUNT
405A000	31000	GALLONS TACK COAT	.75	23,250.00
411A005	8575	TONS BIT PAVEMENT	26.38	226,208.50
411C005	2575	TONS BIT LEVELING	30.00	77,250.00
416A005	2495	TONS BIT CONC SURF	27.88	69,560.60
416C005	750	TONS BIT CONC LVLG	32.00	24,000.00
600A000	1	LUMP MOBILIZATION	LUMP	6,000.00
701A002	3	MILES TRAF STRIPE	500.00	1,500.00
701A004	24	MILES TRAF STRIPE	190.00	4,560.00
701A010	14	MILES TRAF STRIPE	500.00	7,000.00
701A014	11	MILES TRAF STRIPE	985.00	10,835.00
701C000	33	MILES TEMP STRIPE	225.00	7,425.00
701C001	10	MILES TEMP STRIPE	275.00	2,750.00
703A002	2050	SQ FT TRAF MARKGS	1.25	2,562.50
703B002	80	SQ FT TRAF LGNDS	1.50	120.00
705B001	180	EA PAVMT MRKRS	3.50	630.00
705B002	270	EA PAVMT MRKRS	3.50	945.00
705B004	620	EA PAVMT MRKRS	3.75	2,325.00
740B000	1057	SQ FT CONSTRC SIGNS	10.00	10,570.00
740E000	140	EA CONES 36"	15.00	2,100.00
740I001	6	EA WARNING LIGHTS	100.00	600.00
741C000	2	EA SEQ ARROW UNIT	4000.00	8,000.00
		TOTALS		488,191.60

Table 2

dBASE III database file structure

Field	Field name	Type	Width	Dec
1	PROJ_NO.	Numeric	3	
2	LENGTH	Numeric	6	3
3	ZONE	Numeric	1	
4	BID_DATE	Date	8	
5	ITEM_NO	Character	7	
6	QUANTITY	Numeric	7	
7	DESCRIPT	Character	22	
8	ITEM_AMT	Numeric	11	2
9	COST	Numeric	11	2
** Total **			77	

The organization of a relational database into rows and columns permits many relational operations of dBASE III software to be used. An example of this matrix arrangement in rows and columns is shown in Figure 1. Each row contains information that belongs to a given entry in the database. The data within a row is subdivided into several items that are held in the columns in the table. Each row is a data record and each column is a data field. A data field can be assigned a field name, which may be an alphanumeric string or a label. In dBASE III five types of fields are available to accommodate different kinds of data elements. These five types of fields are character, memo, numeric, logical and date. A character field and a memo field are reserved for holding alphanumeric data. Numbers or values are stored in a numeric field. Dates are saved in a date field in the form of dd/mm/yy. A logical field is used to contain a character that represents a true or false state in a logical expression. In the example data base file structure, Table 2, only the numeric, character and date fields were used. The width of a field is the amount of space, in characters, allocated to the data entry. The term 'dec' is an abbreviation for decimal and indicates the amount of character space to the right of the decimal point reserved for decimal entry. The amount of character space reserved for decimal entry is included in the total width of a field. In the database established for the AHD data an example of a

data field was 'QUANTITY', which represented the specific quantity for a material. As each data record is entered, it is given a number. This number represents the order in which the data item is stored in the data base file. The different parts of the record fall into different columns, or fields. As a result any data element in the database can be identified by its record number and field name. This fact is extremely useful in performing dBASE III operations such as sorting and indexing files.

Indexing is the creation of an index file. An indexed file is a database file on which an indexing operation has been performed. This operation temporarily rearranges the contents of a specified database file in a specific manner and achieves the effect of a sorting operation. The format of an INDEX Command is:

```
.USE <File Name>
.INDEX ON <Name of key field> TO <Name of Index File>
```

The SORT Command is similar to indexing. However, the SORT command rearranges the data records of an active database file in ascending or descending order based on the contents of the key field. The format of a basic SORT Command is:

```
.USE <File Name>
.SORT TO <Name of sorted file> ON <Name of key field>.
```

Several of the capabilities and limitations of dBASE III have been discussed. Another important factor in data

base management is the ability of the user to access data and the speed at which the computer accesses the data. As previously discussed the IBM PC-AT microcomputer can be configured with different types of floppy and hard disk drives. In processing or performing relational operations on dBASE III database files the importance of using a hard disk can not be overestimated. Present hard disk drives allow the user to store anywhere from 5 to 150 megabytes of information. This is a considerable increase over the 80 k-bytes to 1.2 megabytes capacity offered by floppy disk drives. The hard disk has the distinct advantage over a floppy disk of reducing data access time. A hard disk spins at approximately 3600 rpm, whereas, a floppy disk rotates at 320 rpm. This enables the hard disk system to read and write to a database file many times faster than the floppy disk drive (4). It is recommended that when using dBASE III the microcomputer be configured with a hard disk drive and a minimum of 512 k-bytes of RAM. During operation dBASE III uses all available RAM, and it is possible to run out of memory in some applications if not configured with adequate RAM.

dBASE III Command Files

The use of dBASE III in the batch processing mode offers all of the power and flexibility necessary for designing an integrated menu-driven data base management system. In dBASE III the method of using the batch

processing mode is through the use of a special file called a command file. A command file consists of program lines, each of which instructs the computer to perform a specific operation. A command file provides the capability to save a group of commands so they may be used as a group without retyping them each time. The commands can be entered in the command file through the text editing program, which is part of dBASE III; or the command file can be created by a word-processing program in nondocument mode. In dBASE III, the file identifier for command files is .PRG.

Since dBASE III is also a programming language certain procedures must be followed as with any other programming language to avoid errors. To avoid ambiguity, each instruction must follow the specific syntax rules that govern legitimate programming format and the semantic rules that determine the meaning of a command. In most cases, the semantic rules of dBASE III follow the rules of the English language. The syntax rules of dBASE III require that each command line begin with a verb. The maximum length of a command line is 256 characters and the command line must end with a RETURN. Some examples of command line grammar are:

<verb>	<adverb>	<object>	<prepositional phrase>
USE		Datafile	
SET		TALK	ON
INDEX	ON Keyfield		TO Index File

The command file, as a batch file, is executed with a DO

<Command File Name> Command. The only commands that close command files are: RETURN; CANCEL; or QUIT.

In development of the preliminary cost estimating procedure for the AHD, command files were used extensively. A command file for each project category analyzed was used to calculate the mean quantity of material used, the standard deviation of quantity of material used, the coefficient of variation, the total individual dominant material cost for all projects, and the percentage of the total project cost represented by the individual dominant material cost.

LIST PROJ_NO,LENGTH,ZONE,BID_DATE,ITEM_NO,QUANTITY,DESCRIPT,;
ITEM_AMT,COST

Record#	PROJ_NO	LENGTH	ZONE	BID_DATE	ITEM_NO	QUANTITY	DESCRIPT	ITEM_AMT	COST
1	10	12.950	3	09/28/84	405A000	31000	GAL TACK COAT	23250.00	1795.37
2	10	12.950	3	09/28/84	411A005	8575	TONS BIT PAVMT	226208.50	17467.84
3	10	12.950	3	09/28/84	411C005	2575	TONS BIT PAVMT LVL	77250.00	5965.25
4	10	12.950	3	09/28/84	416A005	2495	TONS BIT CONC WEAR SUR	69560.60	5371.47
5	10	12.950	3	09/28/84	416C005	750	TONS BIT CONC MIX LVL	24000.00	1853.28
6	10	12.950	3	09/28/84	600A000	1	LUMP SUM MOBILIZATION	6000.00	463.32
7	10	12.950	3	09/28/84	701A002	3	MI BRKN WHT TRAF STRP	1500.00	115.83
8	10	12.950	3	09/28/84	701A004	24	MI SLD WHT TRAF STRP	4560.00	352.12
9	10	12.950	3	09/28/84	701A010	14	MI BRKN YLW TRAF STRP	7000.00	540.54
10	10	12.950	3	09/28/84	701A014	11	MI SLD YLW TRAF STRP	10835.00	836.68
11	10	12.950	3	09/28/84	701C000	33	MI BRKN TEMP TRAF STRP	7425.00	573.36
12	10	12.950	3	09/28/84	701C001	10	MI SLD TEMP TRAF STRP	2750.00	212.36
13	10	12.950	3	09/28/84	703A002	2050	SF TRAF CNTRL MRKS	2562.50	197.88
14	10	12.950	3	09/28/84	703B002	80	SF TRAF CNTRL LGNDS	120.00	9.27
15	10	12.950	3	09/28/84	705B001	180	EA PAVMT MRKS	630.00	48.65
16	10	12.950	3	09/28/84	705B002	270	EA PAVMT MRKS	945.00	72.97
17	10	12.950	3	09/28/84	705B004	620	EA PAVMT MRKS	2325.00	179.54
18	10	12.950	3	09/28/84	740B000	1057	SF CONSTRUC SIGNS	10570.00	816.22
19	10	12.950	3	09/28/84	740E000	140	EA CONES	2100.00	162.16
20	10	12.950	3	09/28/84	740I001	6	EA WARNING LIGHTS	600.00	46.33
21	10	12.950	3	09/28/84	741C000	2	EA SEQ ARROW/CHEV	8000.00	617.76

Figure 1

dBASE III Database File:
Maintenance and Resurfacing Category Project #10

IV. DEVELOPMENT OF COST ESTIMATING PROCEDURE: MAINTENANCE AND RESURFACING PROJECT CATEGORY

Database Development

As previously discussed, the introduction of microcomputers such as the IBM PC-AT and database management software like dBASE III has encouraged many businesses and governmental agencies to exploit these new capabilities and conduct research into previously unexplored areas. The availability of microcomputers to engineers and cost estimators has helped to eliminate the past frustration often caused by the time delay and loss of control associated with using mainframe computers. The microcomputer and user friendly software packages have created the means of enhancing productivity and job performance.

The development of a database for examination of AHD bid data was an ideal application of current microcomputer technology provided by the IBM PC-AT microcomputer and DBASE III software package. When creating a database and the necessary database files a decision must first be made as to exactly what information will be stored in the file. In examining the typical bid information provided by the AHD, which was shown in Figure 1 of Chapter III, it was found

that 9 data items per pay item extracted from the bid sheets would provide the required information. The AHD provided 174 low bids awarded during 1984 and early 1985. The bids were further divided into 10 project categories and numbered for administrative control as shown in Table 3.

Since 9 items of information are required for each pay item listed in the bid, a file with 9 fields will be needed. Next, each field is assigned a name, variable type and a maximum length. A typical database file structure was shown in Table 2. The actual data can be entered into the database file by simply typing the information in the designated blanks when displayed on the screen of the computer. The database file created for the AHD data was composed of 9,052 records and required 697,327 bytes of file space.

After the database file was created for all 174 projects, several smaller database files were created through the use of the dBASE III command APPEND for specific project categories. The purpose of creating smaller and more specific database files was to take advantage of the powerful INDEX command of dBASE III and to reduce processing time. The INDEX command can be used to analyze database files to uncover complex relationships that may exist

Table 3

Project Categories

Project Categories	Bid Numbers
Maintenance and Resurfacing	1 - 66
Widening and Resurfacing	67 - 93
Base and Bituminous Pavement	94 - 108
Grade, Drain and Bituminous Pavement	109 - 122
Bridge Replacement, Culverts and Approaches	
South half of Alabama	123 - 132
North half of Alabama	133 - 137
Bridge Replacement and Approaches	138 - 152
Interstate Bituminous Pavement Rehabilitation	153 - 160
Interstate Concrete Pavement Rehabilitation	161 - 164
Interstate Base and Bituminous Pavement	165 - 173
Interstate Grade and Drain	174 - 177

between data fields. The software package dBASE III can also perform a wide variety of statistical tests and mathematical procedures in the batch processing mode using a command file.

Definitions

Before proceeding to the derivation of the cost estimating procedure, several key statistical terms must be defined and several important characteristics of the AHD Bid Tabulation Information System reviewed. The Bid Tabulation Information System is a management reporting system that has its roots in The Standard Specifications for Highway Construction published annually by the AHD (18). In the Bid Tabulation Information System, the AHD describes a material item or work item, commonly referred to in specifications as a pay item, with an alphanumeric numbering system. This alphanumeric numbering system is in consonance with the paragraphs governing the pay items in The Standard Specifications for Highway Construction. The pay item is generally a seven digit alphanumeric code that is listed in ascending order on bid sheets when the pay item is required. In the analysis of project categories for dominant materials using the dBASE III INDEX command, database files were indexed by these pay items and examined for trends and the effects of such factors as project length.

Several statistical properties were used in the derivation of the cost estimating procedure. In the

analysis of project categories, individual projects within the category were further classified by project length. In doing so, project length class intervals were developed. Class intervals are contiguous, nonoverlapping intervals selected in such a way that they are mutually exclusive and exhaustive, that is, each value in the set of data can be placed in one and only one of the intervals (6). The number of class intervals used depends on the number of observations and the amount of scatter or dispersion in the data. Choosing the number of class intervals approximately equal to the square root of the sample size often works well in practice (10).

Further analysis of the dominant materials within each project category selected for analysis was performed with a dBASE III command file. This command file calculated the average quantity of material used on projects within a given category as well as the variance, coefficient of variation and the standard deviation of the material quantity. The variance was important because it provided a measure of the spread of data about the mean (11). The standard deviation is the positive square root of the variance and is a commonly used measure of dispersion. It is a numerical value, in units of the variable itself, that reflects the clustering tendency of the data (3). A large standard deviation is an indication that the distribution of data points will be flat and wide, with some relatively extreme

values possibly observed. If the standard deviation is small, the data points will be more clustered around the center of the data. The coefficient of variation is a measure of relative variation. It is expressed as a fraction or percentage of the mean and is obtained by dividing the standard deviation by the mean. The coefficient of variation is useful when comparing the variability of two or more data sets that differ considerably in the magnitude of observation.

Project Category Overview

In the development of the cost estimating procedure for the AHD, three distinctly different project categories were examined. These categories were: (1) Maintenance and Resurfacing, (2) Bridge Replacement and Approaches and (3) Grade, Base and Drain. The Maintenance and Resurfacing project category was the first category analyzed to develop the preliminary cost estimating procedure for the AHD. This category had 63 bids and the database file consisted of 941 records requiring 72,780 bytes of file space. A typical or average Maintenance and Resurfacing project would have 15 pay items, cost $371,509 and have a project length of 8 miles. During the creation of the database file each project was numbered for identification. In the Maintenance and Resurfacing category, the block of numbers 1 through 66 was assigned. It should be noted that due to an oversight

during the database file creation, project numbers 12, 13 and 14 were not used to designate any project.

Cost Estimating Procedure Derivation

The purpose of the research undertaken was to develop a cost estimating procedure to predict preliminary project costs for the AHD. This cost estimating procedure would require only a rough estimate of material quantities, work items and project length. The methodology makes use of the fact that one-third or less of the pay items used in a project comprise 90 percent or more of the project cost. These pay items that dominate the construction project are referred to as dominant materials. In examination of the Maintenance and Resurfacing category, three typical projects are identified here for meeting the 90 percent of total project cost and one-third or less of the pay items criteria. For example, in project # 9, 2 of 10 pay items comprise 89 percent of the total project cost. In project # 10, 7 of 21 pay items make up 90 percent of the total project cost. Finally, in project # 11, 6 of 23 pay items comprise 95 percent of the total project cost. If the pay items that dominate the bid can be estimated with reasonable accuracy, then a good estimate of the project cost can be calculated.

As determined in earlier research (8) and in construction management courses, the cost per mile for materials in resurfacing projects is affected by:

- The type of overlay;
- The thickness of the overlay;
- The amount of leveling required;
- The length of the project; and,
- The geographic location of the project.

These factors were incorporated into a simple estimating procedure using a base material cost per mile and an adjustment factor based on the standard deviation of material quantity and coefficient of variation. This adjustment factor is used to increase or decrease the base cost per mile if a greater than average quantity or material or work item or a less than average quantity of material or work item is required. Each project within the dBASE III database file ALHWY1.dbf was INDEXed by the multiple fields material cost and project length. In the database file the field material cost is specified as ITEM_AMT, and the field project length is specified as LENGTH. The use of the dBASE III command INDEX resulted in the creation of an indexed file. After the indexing procedure ranked the material cost in ascending order it was easy to determine which materials comprised 90 percent of the total project cost by summing individual material cost from the bottom of each indexed project bid until 90 percent of total project cost was achieved, as shown in Figure 2. A frequency record was kept based on the number of times each pay item appeared in the

dbase III indexed file
Project #1

RECORD#	ITEM_NO	DESCRIPTION	QUANTITY	ITEM_AMT
17	705B003	PAVEMENT MARKERS	40	132.00
14	703B000	SF TRAF CONTROL LEGND	292	438.00
19	705B005	PAVEMENT MARKERS	160	528.00
16	705B002	PAVEMENT MARKERS	285	940.50
18	705B004	PAVEMENT MARKERS	290	957.00
10	701B000	LF DOTTED TRAF STRIPE	4100	1435.00
20	740B000	SF CONSTRUCT SIGNS	268	1742.00
15	705B001	PAVEMENT MARKERS	1210	1815.00
7	701A000	BRKN WHITE TRAF STRIPE	11	1980.00
12	701C001	MI SOLID TRAF STRIPE	5	2150.00
8	701A004	SOLID WHITE TRAF STRIPE	8	2240.00
5	425B001	TONS BIT PLNT MIX FRIC	67	2345.00
21	740D000	CHANNELIZING DRUMS	50	2500.00
22	741B001	PORT ARROW/CHEVRON UNIT	1	3000.00
9	701A012	SOLID YELLOW TRAF STRP	13	3640.00
11	701C000	MI BRKN TRAF STRIPE	12	3960.00
13	703A000	SF TRAF CONTROL MARKG	3977	5965.00*90%
1	405A000	GALLONS TACK COST	11834	11834.00
6	600A000	LUMP SUM MOBILIZATION	1	29000.00
3	416A005	TONS BIT CONC WEAR SUR	2134	70848.00
2	408A000	SY PLANING EXIST PAV	42652	74641.00
4	425A002	TONS BIT PLNT MIX SUR	3727	117027.80

BID $339,119.60 22 PAY ITEMS

90% $305,208.00 6 PAY ITEMS

Figure 2

Maintenance and Resurfacing Category:
dBASE III File Indexed by Ascending Material Cost

group of pay items representing 90 percent of the project cost. In the 63 bids considered in the Maintenance and Resurfacing category, 7 materials were found to dominate these bids as shown in Table 4.

From the project data, 63 project bids were selected from the Maintenance and Resurfacing category. These 63 projects represented all work performed in this category in the State of Alabama during the period October 1, 1983 to January 30, 1985. The projects were further categorized according to length. Three class intervals were selected based on the distribution of the projects when database files were indexed by project length. The length of each class interval was 5 miles. For each category or class interval the average cost of construction per mile was calculated as was the average cost per mile for all projects. The average cost per mile is displayed in Table 5.

From Table 5 the midpoint of each interval was determined. From this the base cost per mile for the value was determined. These points were plotted and graphically connected. The graph developed is shown in Figure 3. This figure provides the cost estimator with the means to determine an accurate base cost per mile for any length within the limits of the graph. The cost estimator would estimate the total project length, represented by the y axis, and read to the right to the intersecting value on the

Table 4

Dominant Materials
Maintenance and Resurfacing Category
63 total bids

ITEM_NO	DESCRIPTION	FREQUENCY OF OCCURRENCE
327D005	Plant Mix Bituminous Base Widening (TON)	31
401A006	Bituminous Treatment G (SYCIP)	11
411A005	Hot Bituminous Pavement (TON)	20
411C005	Hot Bituminous Pavement Leveling (TON)	17
416A005	Bituminous Concrete Wearing Surface (TON)	34
416C005	Bituminous Concrete Leveling (TON)	32
600A000	Lump Sum Mobilization	29

Table 5

Average cost per mile:
Maintenance and Resurfacing Category

# PROJECTS	LENGTH (Miles)	AVG $/MI	TOTAL LENGTH (Miles)	TOTAL COSTS
16	0 - 5.00	$86,787	48.65	$4,222,209
32	5.01-10.00	$48,903	237.97	$11,637,525
15	10.01-15.00	$33,813	223.36	$7,552,469
63		$45,908	509.98	$23,412,203

NOTE: Average $ per mile = Total Cost / Total Length (for each interval).

cost curve. From this intersecting point read down to the x axis and determine the estimated base cost per mile.

Using a dBASE III command file, Figure 4, the following items were calculated for the dominant 7 material items in Table 4:

- Average quantity per mile;
- Standard deviation of the quantity per mile;
- Coefficient of variation of the quantity per mile;
- Total dollar amount for a material for all bids;
- Material cost as a percentage of the average project cost.

The results of the dBASE III command file execution, Figure 5, are displayed in Table 6. In Table 6, the average quantity of material per mile required for a typical project, for the 7 dominant materials, was calculated based on total project length. Since these 7 materials comprise the major cost of the project, their actual percentage of total project cost was determined.

Once the base cost per mile or base material requirement per mile for each dominant material has been determined, an adjustment factor must be developed. This adjustment factor would allow the cost estimator to adjust the material quantity requirement for each dominant material when differing conditions for a project exist from what is

Table 6

Average quantity of material
and
Material cost as a percentage of total project cost

MATERIAL	AVG QUAN/MI		STD DEV QUAN/MI		CV	% OF TOTAL PROJ COST
327D005	404.796	TON	193.28	TON	0.477	9.44
401A006	15943.254	SYCIP	3102.53	SYCIP	0.195	2.86
411A005	870.127	TON	298.19	TON	0.343	15.14
411C005	183.740	TON	146.21	TON	0.796	4.13
416A005	1189.391	TON	672.76	TON	0.566	34.47
416C005	221.949	TON	136.80	TON	0.616	6.76
600A000	0.187		0.185		0.990	4.04

NOTE: Item 600A000 - Lump Sum Mobilization, this value represents the average amount (Mobilization Cost/Length) that may be determined for each project mile. For the 63 bids considered, 61 bids included lump sum mobilization cost. In this case the average project mobilization cost was (\$953,896/61 = \$15,637.64). When considered as an average quantity/mile this equates to 0.187 x \$15,637.64 = \$2924.24 with a standard deviation of \$540.98.

considered a typical project. This adjustment factor allows the estimator to increase or decrease his base cost per mile based on material requirements.

The base cost per mile may be adjusted when it is known that the material quantities used per mile are substantially greater or substantially less than normal. Table 7 indicates three levels of anticipated material quantity usage: (1) average - used on a typical project, (2) upper limit (UL) - used on a project requiring more material than a typical project, and (3) lower limit (LL) - used on a project requiring less material than a typical project. For each of the 7 dominant materials the value of one standard deviation of material quantity was calculated. In an upper limit material quantity requirement, the quantity used is equal to the typical quantity plus one standard deviation. In a lower limit material quantity requirement, the quantity used is equal to the typical quantity minus one standard deviation or zero if a negative requirement occurs. One standard deviation of material quantity was selected as an initial material quantity adjustment to represent the UL and LL values of material quantity. The UL and LL material quantity values may be increased or decreased by the estimator to improve accuracy.

A comparison of the estimated average quantity per mile listed in Table 7 with calculated values obtained from the AHD typical sections is listed in Table 8. The typical

Table 7

Estimated material requirements per mile:
Maintenance and Resurfacing Category

MATERIAL	AVG QUAN/MI	UPPER LIMIT (UL) QUANTITY/MI	LOWER LIMIT (LL) QUANTITY/MI
327D005	405 TON	598 TON	212 TON
401A006	15943 SYCIP	19046 SYCIP	12840 SYCIP
411A005	870 TON	1168 TON	572 TON
411C005	184 TON	330 TON	38 TON
416A005	1189 TON	1862 TON	516 TON
416C005	222 TON	359 TON	85 TON
600A000	$2,924.24	$3,465.22	$2,383.26

values obtained from the AHD were arrived at through independent analysis. These values are used by the AHD in the preliminary estimating process to determine estimated material quantities. The application rate is the amount of material that is applied to a typical section that is twenty-four feet wide and results in the AHD calculated value.

From the average quantity per mile values contained in Table 7 and values of the coefficient of variation and material cost as a percentage of total project cost obtained from a dBASE III command file a base cost adjustment guide was developed. The percentage of the base cost per mile that each dominant material contributes is reflected in the following relationship:

% of Base Cost = Coefficient of Variation X % Item Cost as a % of Total Project Cost;

where, coefficient of variation (CV) = (Standard Deviation) / (Average Quantity per mile)

For example, 416A005:

$$CV = 673 / 1189 = 0.566$$

% of Total Cost of item 416A005 for all projects :

where, Total Cost all projects = $23,412,203.00 (Table 5)
Total Cost item 416A005 = $ 8,136,166.00 (Figure 4)

$$\% = \$8,136,166.00 / \$23,412,203.00 = 0.3475 = 34.75\ \%$$

$$\text{Adjustment Factor} = CV \times \%\ \text{Item Cost} = 0.566 \times 34.75\ \% = 20\ \%$$

Table 8

Typical dominant material section quantities:
Maintenance and Resurfacing Category

MATERIAL	ESTIMATED AVG QUAN/MI		AHD CALCULATED AVG QUAN/MI		APPLICATION RATE
401A006	15943	SYCIP	16427	SYCIP	
411A005	870	TON	739	TON	105#/SY-24'
416A005	1189	TON	1056	TON	150#/SY-24'
416C005	222	TON	281	TON	40#/SY-24'

As a result of similar calculations for the 7 dominant material items the following estimating guide was developed as shown in Table 9.

Sample Calculation

In order to perform a sample calculation Table 9 and Figure 3 are used. Figure 3 is used to determine the base cost per mile based on an estimated project length. Table 9 is used as a cost adjustment guide for material quantity variation.

EXAMPLE: What is the projected cost of a proposed Maintenance and Resurfacing project 4.5 miles in length if it is expected to use a greater than average thickness of Bituminous Concrete Wearing Surface (416A005)?

SOLUTION:

1. Given: Project length 4.5 miles.

   From Figure 3 - Determine Base Cost per mile.

   Base Cost per mile = $68,000.00 (Typical Project)

2. Cost of a typical Maintenance and Resurfacing project 4.5 miles in length.

   Typical Cost = Project Length X Base Cost per mile
   = 4.5 X $68,000.00
   = $306,000.00

3. How much must this base estimate be increased to allow for a greater than average thickness of the wearing surface?

   From Table 9 - Adjustment Factors

   Bituminous Concrete Wearing Surface (416A005)
   = increase + 20 %

Table 9

Base cost adjustment factors:
Maintenance and Resurfacing Category

Alter Base Cost by + or - percentage stated below.

MATERIAL	PROJECT LENGTH (miles) 0 - 5.0	PROJECT LENGTH (miles) 5.01 - 10.0	PROJECT LENGTH (miles) 10.01 - 15.00
416A005	20%	20%	20%
411A005	5%	5%	5%
327D005	5%	5%	5%
416C005	4%	4%	4%
600A000	4%	4%	4%
411C005	3%	3%	3%
401A006	1%	1%	1%

Total Adjustment = increase + 20 %

4. Project cost adjusted for material quantiy variation.

New Cost = Typical Cost + Material Adjustment Cost
= \$306,000.00 + (20% X \$306,000.00)
= \$367,200.00

A closer examination of the Base Cost Adjustment Factors Table 9 and Material Cost as a Percentage of Total Project Cost Table 6 results in the detailed costs listed in Table 10 for the example project in the sample calculation based on dominant material.

In the example in the sample calculation the construction base cost per mile was adjusted for an increases in the requirement for Bituminous Concrete Wearing Surface (416A005). Accordingly the base cost per mile was increased, in accordance with Table 9, by 20 per cent. The result of this increase is reflected in Table 11.
Table 11 reflects the detailed breakdown of the adjusted base cost obtained in the sample calculation. The adjusted base cost is as follows:

Base Cost per mile:	\$68,000.00
Adjustment Factor :	+ 20%
Increase in Base Cost:	\$13,600.00
Adjusted Base Cost:	\$81,600.00 (120% of Base Cost)

Summary

The State of Alabama Highway Department (AHD) presently has the ability to predict unit prices for highway construction materials by regression analysis of historical material price data (8). By examining the variables of

Table 10

Detailed material costs:
base cost per mile sample calculation
Maintenance and Resurfacing Category

PROJ LNGTH	BASE COST	MATERIAL	% BASE COST OF MATERIAL	BASE COST/MI OF MATERIAL
4.5 MI	$68,000.00	416A005	34.47%	$23,439.60
		411A005	15.14%	$10,295.20
		327D005	9.44%	$ 6,419.20
		416C005	6.76%	$ 4,596.80
		411C005	4.13%	$ 2,808.40
		600A000	4.04%	$ 2,747.20
		401A006	2.86%	$ 1,944.80
		SUB TOTAL	76.84%	$52,251.20
		ALL OTHER	23.16%	$15,748.80
		TOTAL	100.0%	$68,000.00

Table 11

Detailed material costs:
adjusted base cost per mile sample calculation
Maintenance and Resurfacing Category

PROJ LNGTH	BASE COST	MATERIAL	% BASE COST OF MATERIAL	BASE COST/MI OF MATERIAL
4.5 MI	$81,600.00	416A005	54.47%	$37,039.60
		411A005	15.14%	$10,295.20
		327D005	9.44%	$ 6,419.20
		416C005	6.76%	$ 4,596.80
		411C005	4.13%	$ 2,808.40
		600A000	4.04%	$ 2,747.20
		401A006	2.86%	$ 1,944.80
		SUB TOTAL	96.84%	$65,851.20
		ALL OTHER	23.16%	$15,748.80
		TOTAL	120.0%	$81,600.00

quantity, zone and material type codes, a regression model was developed to accurately predict unit price of a material for comparison to unit price bids submitted by bidding contractors. This procedure has been used with success by the AHD to estimate the cost of a project. However, this estimating system did not allow for the estimating of future construction costs for jobs still in the preliminary planning stage. In the development of this cost estimating model, 63 successful bids from 1984 and 1985 were entered into a computer database. Using the software package dBASE III and an IBM PC-AT microcomputer the Maintenance and Resurfacing project category was analyzed for trends within or between database fields. These fields included such data as unit prices, the effect of geographical location on unit price, the effect of project length on unit price, and the determination of what materials dominated the cost of a project. Several distinct conclusions can be drawn from these analyses:

1. The bids are dominated by one-third or fewer of the total pay items, and these pay items generally comprise 90 percent of the total project cost.
2. The geographic location within the State of Alabama has little effect on the unit price of materials.
3. The cost of highway construction or maintenance

is affected by project length. The cost per mile decreases as the length of the project increases.

4. The dominance of a bid by specific pay items applies to small and large projects alike. No matter how large the project, fewer than one-third of the pay items will comprise 90 percent of the project cost.

From the estimating procedure a base cost per mile can be determined for a roadway based on project length. In this case the interval was established as: 0 - 5 miles, 5.01 miles to 10.00 miles, and greater than 10.01 miles. The cost of the project per mile can be adjusted to allow for either an increase or decrease in material quantity required when the material quantity deviates substantially from the quantity required for a typical job. This procedure relies upon determining the mean and standard deviation for a dominant material. The mean establishes a base line requirement for quantity per mile required on a normal job. The standard deviation represents the quantity of material that must either be added to or subtracted from the base amount to allow for variations in layer thickness or other requirements. The coefficient of variation is used to determine the cost to be added to or subtracted from the base cost per mile when material quantity requirements differ substantially from a typical project. The coefficient of variation is multiplied by the percent of

total project cost that is represented by the material item being adjusted. This cost is then added to or subtracted from the base cost per mile which results in the new estimated cost per mile. It can be seen that as the amount of material required in a project increases, the unit price of the material decreases in a nonlinear relationship (8).

The procedure developed provides the AHD with the means to estimate future project costs, on a cost per mile basis, with only preliminary material quantity estimates. The procedure makes use of historical data which provides the most accurate determination of cost.

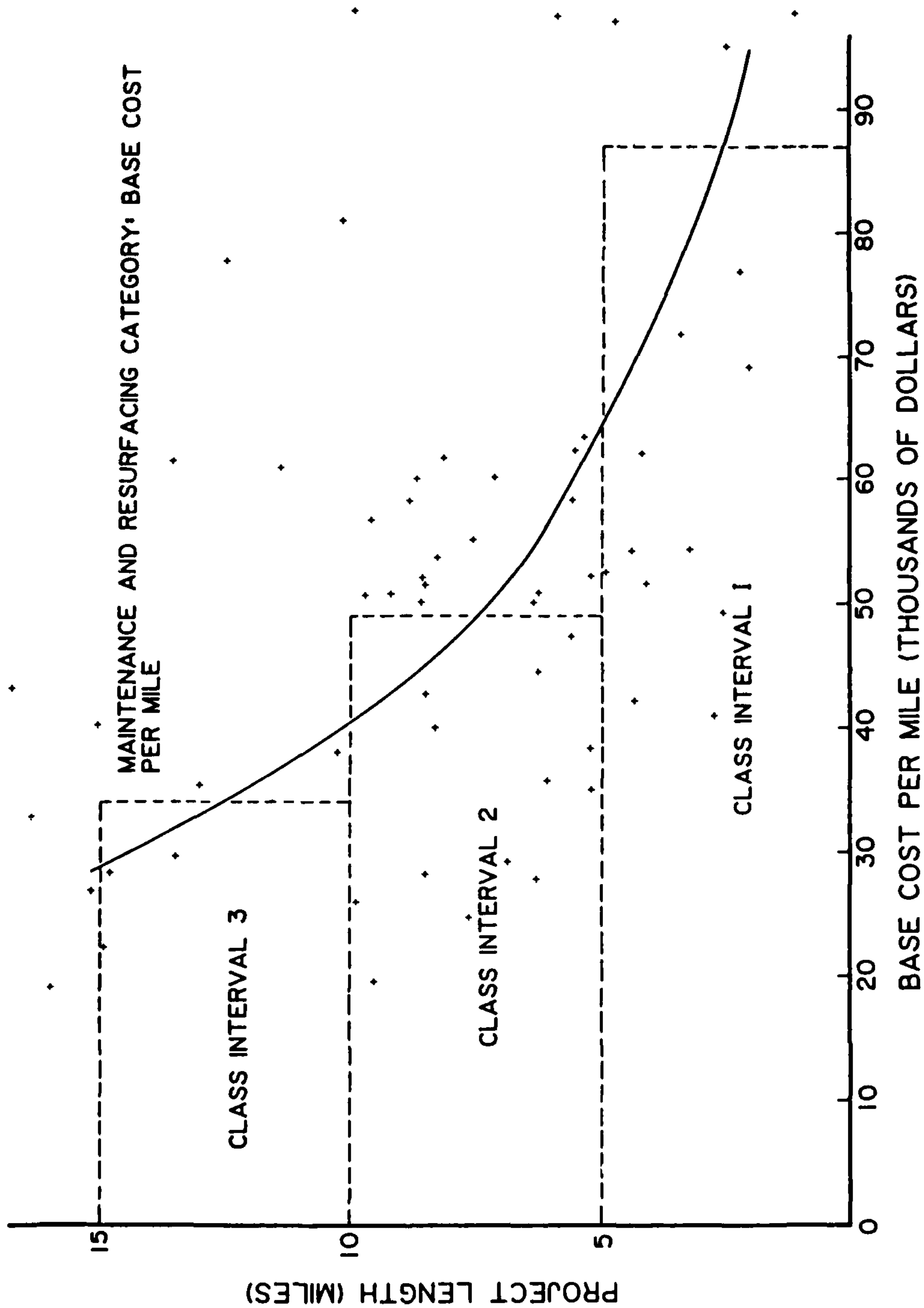

Figure 3

Base Cost per Mile:
Maintenance and Resurfacing Category

```
SET COLOR TO 7/4,4,4
USE ALHWY1.DBF
SET TALK OFF
INPUT "ENTER ITEM_NO IN DOUBLE QUOTES  :" TO A
AVERAGE QUANTITY/LENGTH FOR ITEM-NO = A .AND. QUANTITY>0 TO AVG
COUNT FOR ITEM_NO = A .AND. COST>0 TO N
GO TOP
S=0
T=0
DO WHILE .NOT. EOF()
IF PROJ_NO<67
IF A=ITEM_NO
IF COST>0
C=QUANTITY/LENGTH
T=T+(C-AVG)*(C-AVG)
S=S+ITEM_AMT
ENDIF
ENDIF
ENDIF
SKIP
ENDDO
?
?"FOR THE ITEM_NO",A
?"THE NUMBER OF RECORDS IN THE FILE IS",N
?"THE AVERAGE VALUE OF THE QUANTITY/MILE IS",AVG
Q=SQRT(T/(N-1))
?"THE VALUE OF THE STANDARD DEVIATION IS",Q
V=Q/AVG
?"THE VALUE OF THE COEF OF VARIATION IS",V
R=S/23405067
?
?"THE TOTAL $ AMOUNT IS",S
?"THE % FOR THE AVG PROJECT IS",R
RETURN
```

Figure 4

dBASE III Command File:
Maintenance and Resurfacing Category

```
.DO DBASE1A
 ENTER ITEM_NO IN DOUBLE QUOTES:"327D005"

 FOR THE ITEM_NO 327D005
 THE NUMBER OF RECORDS IN THE FILE IS              31
 THE AVERAGE VALUE OF THE QUANTITY/MILE IS     404.796
 THE VALUE OF THE STANDARD DEVIATION IS        193.276926
 THE VALUE OF THE COEF OF VARIATION IS           0.477467
 THE TOTAL $ AMOUNT IS                      2228108.81
 THE % FOR THE AVG PROJECT IS                     0.10


.DO DBASE1A
 ENTER ITEM_NO IN DOUBLE QUOTES:"416A005"

 FOR THE ITEM_NO 416A005
 THE NUMBER OF RECORDS IN THE FILE IS              39
 THE AVERAGE VALUE OF THE QUANTITY/MILE IS    1189.391
 THE VALUE OF THE STANDARD DEVIATION IS        672.760904
 THE VALUE OF THE COEF OF VARIATION IS           0.565635
 THE TOTAL $ AMOUNT IS                      8136166.32
 THE % FOR THE AVG PROJECT IS                     0.35
```

Figure 5

Maintenance and Resurfacing Category:
dBASE III Command File Output

V. DEVELOPMENT OF COST ESTIMATING PROCEDURE: BRIDGE REPLACEMENT AND APPROACHES CATEGORY

Project Category Overview

The second project category analyzed in the development of the future cost estimating procedure was the Bridge Replacement and Approaches category. This category had 15 projects and the database file consisted of 1155 records requiring 89,258 bytes of file space. A typical or average Bridge Replacement and Approaches project would have 77 pay items, cost $1,291,130, have a bridge length of 490 feet, and a total project length of 3648 feet. Projects within the Bridge Replacement and Approaches category are identified by project numbers 138 through 152.

Cost Estimating Procedure Derivation

Applying the estimating procedure previously developed for the Maintenance and Resurfacing category to the Bridge Replacement and Approaches category, it is evident that the same criteria apply and the same method may be used. In the Bridge Replacement and Approaches category are 15 projects from 1984. Examination of the bids indicates that ninety percent of the projects' cost is represented by one-third or less of the pay items. Following the procedure previously

developed for the Maintenance and Resurfacing category, each project within the database file was INDEXed by material cost. In the database the field material cost was specified as ITEM_AMT. After the indexing procedure each pay item was counted and its cost summed from the bottom of the indexed project bid until 90 percent of the total project cost was achieved as shown in Figure 6. A frequency record was kept based on the number of times each pay item appeared in the group of pay items representing 90 percent of the project cost. In the 15 bids considered in the Bridge Replacement and Approaches category, the 18 materials listed in Table 12 were found to dominate these projects and the contractors' bids.

To facilitate the development of the cost estimating procedure for the Bridge Replacement and Approaches category, separate tables are provided for both bridge length and project length. This provides the means to estimate project cost based on either the bridge length or total project length.

The 15 projects used in development of the cost estimating procedure represented all work performed in this category during 1984. The projects were further categorized according to project length or bridge length. In each case the number of length categories or class intervals selected was three. The average cost per foot was determined for

Table 12

Dominant Materials:
Bridge Replacement and Approaches Category
15 total bids

ITEM_NO	DESCRIPTION	FREQUENCY OF OCCURRENCE
510C010	Reinf Conc Bridge Superstructure	15
513B004	Prestressed Conc Girder (ft)	14
600A000	Lump Sum Mobilization	13
201A000	Clearing and Grubbing	15
210D000	Borrow Excavation (CYIP)	9
510A000	Bridge Substructure Concrete (CY)	15
505C001	Steel Piling (ft)	14
610C001	Loose Rip Rap (TON)	13
206A000	Removal of Old Bridge (Lump Sum)	11
450B000	Reinforced Concrete Bridge End (SY)	15
502A000	Steel Reinforcement (lb)	11
210A000	Unclassified Excavation (CYIP)	12
327A005	Plant Mix Bituminous Base (TON)	7
414A005	Bituminous Concrete Binder Layer (TON)	13
416A005	Bituminous Concrete Wear Surface (TON)	13
505C000	Steel Piling (ft)	13
508A000	Structural Steel (lb)	14
665J000	Silt Fence (ft)	8

both bridge length and project length and each is displayed in Table 13 and Table 14, respectively.

From Table 13 the midpoint of each interval was determined and the base cost per foot for this value was calculated. These points were graphically connected and a graph was developed as shown in Figure 7. Figure 7 provides the cost estimator with the means to determine an accurate Base Cost per foot for any bridge length. The cost estimator would estimate the bridge length, defined on the y axis, and read to the right to the intersecting value on the cost curve. From this intersecting value read down to the x axis and determine the estimated base cost per foot. Similarly, from Table 14 a graph was developed to provide the estimator with a base cost per foot based on project length as shown in Figure 8. A comparison of Figure 7 and Figure 8 shows that the base cost per foot based on bridge length is approximately ten times greater than the base cost per foot based on project length.

Using a dBASE III command file shown in Figure 9 the following items were calculated for the 18 dominant material items for the Bridge Replacement and Approaches category:

- Average quantity per mile;
- Standard deviation of the quantity per mile;
- Coefficient of variation of the quantity per mile;

Table 13

Average cost per foot:
based on
bridge length in feet
Bridge Replacement and Approaches Category

# PROJECTS	LENGTH (feet)	AVG $/ft	TOTAL LENGTH (feet)	TOTAL COST
6	0 - 300	$4,148	1264	$5,243,104
4	301 - 600	$2,342	1749	$4,095,759
5	601 - 900	$1,901	4336	$8,245,211
15		$2,393	7349	$17,584,074

Table 14

Average cost per foot:
based on
project length in feet
Bridge Replacement and Approaches Category

# PROJECTS	LENGTH (feet)	AVG $/ft	TOTAL LENGTH (feet)	TOTAL COST
3	0 - 2000	$400	3638	$1,454,677
8	2001 - 4000	$345	24849	$8,551,881
4	4001 - 6000	$321	23544	$7,577,516
15		$338	52031	$17,584,074

NOTE: For both bridge length and project length the Average $ per foot = Total Cost / Total Length (ft) for each interval.

- Total dollar amount for a material for all bids;
- Material cost as a percentage of the average project cost.

Table 15 is a listing of values obtained when the dBASE III command file of Figure 10 was executed. In Table 15 the average quantity of material per foot required for a typical project, for the 18 dominant materials, was calculated based on total project length. Since these 18 materials comprise the major cost of the project, their actual percentage of total project cost was determined. In Table 16, the average quantity of material per foot required for a typical project, based on bridge length, for the 18 dominant materials was determined. When using bridge length as the base for estimating, the cost per foot is significantly greater as is the average quantity of material per foot. The cost of the project and the quantity of materials required is the same whether the estimator uses project length or bridge length as the measure of the construction project.

Once the base cost per foot or base material requirement per foot for each dominant material has been determined, an adjustment factor must be developed. This adjustment factor would allow the cost estimator to adjust the material quantity requirement for each dominant material when differing conditions for a project exist from what is considered a typical project. This adjustment factor allows

Table 15

Average quantity of material
and
Material cost as a percentage of total project cost
based on total project length in feet
Bridge Replacement and Approaches Category

MATERIAL	AVG QUAN/ft	STD DEV QUAN/ft	CV	% OF TOTAL PROJ COST
510C010	$37.79	$59.88	1.585	10
513B004	0.98 ft	0.90 ft	0.917	9
600A000	$13.27	$20.55	1.548	4
201A000	$14.70	$21.93	1.492	4
210D000	11.76 cy	15.86 cy	1.349	4
510A000	0.09 cy	0.08 cy	0.870	5
505C001	0.69 ft	0.63 ft	0.922	3
610C001	0.67 ton	0.66 ton	0.988	3
206A000	$ 5.60	$ 8.32	1.485	2
450B000	0.17 sy	0.18 sy	1.065	2
502A000	13.85 lb	11.29 lb	0.815	2
210A000	5.87 cy	2.96 cy	0.504	3
327A005	0.45 ton	0.23 ton	0.521	2
414A005	0.23 ton	0.11 ton	0.476	2
416A005	0.17 ton	0.08 ton	0.464	2
505C000	0.36 ft	0.44 ft	1.230	1
508A000	3.69 lb	3.80 lb	1.029	1
665J000	0.87 ft	0.80 ft	0.920	1

Table 16

Average quantity of material
and
Material cost as a percentage of total project cost
based on bridge length in feet
Bridge Replacement and Approaches Category

MATERIAL .sk	AVG QUAN/ft		STD DEV QUAN/ft		CV	% OF TOTAL PROJ COST
510C010	$273.68		$433.58		1.585	10
513B004	6.94	ft	6.37	ft	0.917	9
600A000	$ 98.36		$153.92		1.548	4
201A000	$104.10		$155.33		1.492	4
210D000	83.26	cy	112.29	cy	1.349	4
510A000	0.64	cy	0.57	cy	0.870	5
505C001	4.88	ft	4.46	ft	0.922	3
610C001	4.74	ton	4.67	ton	0.988	3
206A000	$ 37.43		$ 55.58		1.485	2
450B000	1.20	sy	1.27	sy	1.065	2
502A000	98.06	lb	79.93	lb	0.815	2
210A000	41.56	cy	20.96	cy	0.504	3
327A005	3.19	ton	1.63	ton	0.521	2
414A005	1.63	ton	0.78	ton	0.476	2
416A005	1.20	ton	0.57	ton	0.464	2
505C000	2.55	ft	3.12	ft	1.230	1
508A000	39.74	lb	40.93	lb	1.029	1
665J000	9.37	ft	8.62	ft	0.920	1

NOTE: Items 201A000, 206A000, 510C010 and 600A000 are traditionally bid as a lump sum item. In order to make a meaningful estimate of the cost of these items it is necessary to convert them to a cost per foot basis since their unit of measurement is monetary. The average quantity per foot is actually Dollars per foot, and is determined by dividing Material Cost by Length, where length is either the total project length or bridge length. Subsequently, a different value for average quantity per foot is calculated for each respective estimating category, bridge length or project length. Tables 17, 18, and 19 provide the cost estimator with a meaningful measure of these item costs based on calculating the project cost using either bridge length or project length as the estimating baseline.

Table 17

Average lump sum material cost per project:
Bridge Replacement and Approaches Category

MATERIAL	# PROJECTS	COST	AVG COST/PROJECT	CV
201A000	15	$ 765,000	$ 51,000	1.492
206A000	14	$ 272,500	$ 19,464	1.485
510C010	14	$1,741,950	$124,425	1.585
600A000	14	$ 662,864	$ 47,347	1.548

Table 18

Average lump sum material cost per bridge foot:
based on
bridge length in feet
Bridge Replacement and Approaches Category

MATERIAL	AVG $/ft	BRIDGE LENGTH (feet)	STD DEV (lump sum)	STD DEV
201A000	$104.10	7349	4.084	$155.33
206A000	$ 37.43	7280	4.293	$ 55.58
510C010	$273.68	6365	4.211	$433.58
600A000	$ 98.36	6739	4.283	$153.92

Table 19

Average lump sum material cost per project foot:
based on
project length in feet
Bridge Replacement and Approaches Category

MATERIAL	AVG $/ft	PROJECT LENGTH (feet)	STD DEV (lump sum)	STD DEV
201A000	$14.70	52031	4.084	$21.93
206A000	$ 5.60	48657	4.293	$ 8.32
510C010	$37.79	46091	4.211	$59.88
600A000	$13.27	49934	4.283	$20.55

NOTE: STD DEV ($) is a calculated value that is used to convert material items historically bid as a lump sum to a more usable and representative measure. In this case the measure of dollars per foot is practical when applied to the estimation of costs. From previously calculated values of $\bar{X}$ (mean) and CV (coefficient of variation), the standard deviation (s) can be found using the formula:

$$CV = s / \bar{X}$$

the estimator to increase or decrease the base cost per foot based on material requirements.

The base cost per foot (project or bridge) may be adjusted when it is known that the material quantities used per foot are substantially greater or substantially less than normal. The following tables indicate three levels of anticipated material quantity usage: (1) average - used on a typical project, (2) upper limit (UL) - used on a project requiring more material than a typical project, and (3) lower limit (LL) - used on a project requiring less material than a typical project. For each of the 18 dominant materials the value of one standard deviation of material quantity was calculated and the resulting material quantities are listed in Tables 20 and 21 , based on either the project length or bridge length baseline. In a upper limit average material quantity requirement, the quantity used is equal to the typical quantity plus one standard deviation. In a lower limit material quantity requirement, the quantity used is equal to the typical quantity minus one standard deviation or zero if a negative requirement occurs. One standard deviation of material quantity was selected as an initial material quantity adjustment to represent the UL and LL values of material quantity. The UL and LL material quantity values may be increased or decreased by the estimator to improve accuracy.

Table 20

Estimated material requirement per foot:
based on total project length in feet
Bridge Replacement and Approaches Category

MATERIAL	AVG QUAN/ft	UPPERLIMIT(UL) Quantity/ft	LOWER LIMIT (LL) Quantity/ft
510C010	$37.79	$97.67	0
513B004	0.98 ft	1.88 ft	0.08 ft
600A000	$13.27	$33.82	0
201A000	$14.70	$36.63	0
210D000	11.76 cy	27.62 cy	0
510A000	0.09 cy	0.17 cy	0.01 cy
505C001	0.69 ft	1.32 ft	0.03 ft
610C001	0.67 ton	1.33 ton	0.01 ton
206A000	$ 5.60	$13.92	0
450B000	0.17 sy	0.35 sy	0
502A000	13.85 lb	25.14 lb	2.56 lb
210A000	5.87 cy	8.83 cy	2.91 cy
327A005	0.45 ton	0.68 ton	0.22 ton
414A005	0.23 ton	0.43 ton	0.12 ton
416A005	0.17 ton	0.25 ton	0.09 ton
505C000	0.36 ft	0.80 ft	0
508A000	3.69 lb	7.49 lb	0
665J000	0.87 ft	1.67 ft	0.07 ft

Table 21

Estimated material requirement per foot:
based on bridge length in feet
Bridge Replacement and Approaches Category

MATERIAL	AVG QUAN/ft	UPPER LIMIT (UL) Quantity/ft	LOWER LIMIT (LL) Quantity/ft
510C010	$273.68	$707.26	0
513B004	6.94	13.31 ft	0.57 ft
600A000	$ 98.36	$252.28	0
201A000	$104.10	$259.43	0
210D000	83.26 cy	195.55 cy	0
510A000	0.64 cy	1.21 cy	0.07 cy
505C001	4.88 ft	9.34 ft	0.42 ft
610C001	4.74 ton	9.41 ton	0.07 ton
206A000	$ 37.43	$ 93.01	0
450B000	1.20 sy	2.47 sy	0
502A000	98.06 lb	177.99 lb	18.13 lb
210A000	41.56 cy	62.52 cy	20.60 cy
327A005	3.19 ton	4.82 ton	1.56 ton
414A005	1.63 ton	2.41 ton	0.85 ton
416A005	1.20 ton	1.77 ton	0.63 ton
505C000	2.55 ft	5.67 ft	0
508A000	39.74 lb	80.67 lb	0
665J000	9.37 ft	17.99 ft	0.75 ft

A dBASE III command file was used to calculate the values of the coefficient of variation and material cost as a percentage of total project cost for each dominant material. These values were previously listed in Tables 15 and 16. From these factors a base cost estimating guide was developed. The percentage of the base cost that each dominant material contributes is reflected in the following relationship:

% of Base Cost = Coefficient of Variation X % Item Cost as a % of Total Project Cost;

where, coefficient of variation (CV) = Standard Deviation/Average Quantity per ft.

For example, 513B004 : (From Table 15)

$$CV = 0.90 / 0.98 = 0.917$$

% of Total Cost of item 513B004 for all projects:

where, Total Cost all projects = \$17,584,074.00 (Table 13)
Total cost item 513B004 = \$ 1,592,938.00 (Figure 9)

$$\% = \$1,592,938/\$17,584,074 = 0.0906 = 9\%$$

$$\text{Adjustment Factor} = CV \times \%\ \text{Item Cost} = 0.92 \times 9\ \% = 8\%$$

As a result of similar calculations for all dominant materials, the estimating guide shown in Table 22 was developed.

Table 22

Base cost adjustment factors:
Bridge Replacement and Approaches Category

Alter Base Cost by + or - percentage stated below.

MATERIAL	UNIT	PROJECT LENGTH 0-2000 OR BRIDGE LENGTH 0-300	PROJECT LENGTH 2001-4000 OR BRIDGE LENGTH 301-600	PROJECT LENGTH 4001-6000 OR BRIDGE LENGTH 601-900
510C010	LS	16%	16%	16%
513B004	ft	8%	8%	8%
600A000	LS	6%	6%	6%
201A000	LS	6%	6%	6%
210D000	cy	5%	5%	5%
510A000	cy	4%	4%	4%
505C001	ft	3%	3%	3%
610C001	ton	3%	3%	3%
206A000	LS	3%	3%	3%
450B000	sy	2%	2%	2%
502A000	lb	2%	2%	2%
210A000	cy	1.5%	1.5%	1.5%
327A005	ton	1%	1%	1%
414A005	ton	1%	1%	1%
416A005	ton	1%	1%	1%
505C000	ft	1%	1%	1%
508A000	lb	1%	1%	1%
665J000	ft	1%	1%	1%

Sample Calculation

In order to perform a sample calculation, Table 22 and Figures 7 and 8 are used. For a cost estimate based on total project length use Figure 8 to determine the base cost per foot and use Table 22 for the base cost adjustment guide for material quantity variation. For a cost estimate based on bridge length use Figure 7 to determine base cost per foot and use Table 22 for the base cost adjustment guide for material quantity variation.

EXAMPLE 1: What is the projected cost of a proposed Bridge Replacement and Approaches project with a total project length of 1500 feet if it is expected that the project will use the following material items that differ significantly from a typical project?

210D000	Borrow Excavation	- greater than average
510A000	Bridge Substructure Conc	- greater than average
327A005	Plant Mix Bit Base	- less than average

SOLUTION:

1. Given: Project Length 1500 feet.

   From Figure 8 - Determine the base cost per foot.

   Average cost per foot = $388.00 (Typical Project)

2. Cost of a typical project 1500 feet in length:

   Typical Cost = Project Length X Base Cost per ft

   = 1500 X $388.00
   = $ 582,000

3. How much must this base cost estimate be adjusted to allow for greater than average borrow excavation and bridge substructure concrete use, and less than average use of bituminous base plant mix?

   From Table 22 - Adjustment Factors

Borrow Excavation	(210D000)	= increase	+ 5%
Bridge Substr Conc	(510A000)	= increase	+ 4%
Plant Mix Bit Base	(327A005)	= decrease	- 1%
Total Adjustment		= increase	+ 8%

4. Cost of the 1500 foot project adjusted for material quantity variation:

New Cost = Typical Cost + Material Adjustment Cost
= $ 582,000 + (8% X $582,000)
= $ 628,560

EXAMPLE 2: What is the projected cost of a proposed Bridge Replacementand Approaches project with a bridge length of 225 feet if it is expected that the project will use the following material items that differ significantly from a typical project?

210D000	Borrow Excavation	- greater than average
510A000	Bridge Substructure Conc	- greater than average
327A005	Plant Mix Bit Base	- less than average

SOLUTION:

1. Given: Bridge Length 225 FEET.

From Figure 7 - Determine the base cost per foot.

Average cost per foot = $3500.00 (Typical Project)

2. Cost of a typical project with a bridge 225 ft in length.

Typical Cost = Bridge Length X Base Cost per foot
= 225 X $3500.00
= $ 787,500

3. How much must this base estimate be adjusted to allow for greater that average borrow excavation and bridge substructure concrete use; and less than average use of Bituminous base plant mix?

From Table 22 - Adjustment Factors

Borrow Excavation	(210D000)	= increase	+ 5%
Bridge Substr Conc	(510A000)	= increase	+ 4%
Plant Mix Bit Base	(327A005)	= decrease	- 1%
Total Adjustment		= increase	+ 8%

4. Cost of the project adjusted for material quantity variation.

   New Cost = Typical Cost + Material Adjustment Cost
   = $ 787,500 + (8% X $ 787,500)
   = $ 850,500

A closer examination of the material cost as a percentage of total project cost Table 15 and Figure 8 reveals the following cost per foot for a project based on the dominant materials and a Project Length of 1500 feet as shown in Table 23.

In Example 1 of the Sample Calculation the construction base cost per foot was adjusted for an increase or decrease in the requirement for the following materials:

Borrow Excavation	(210D000)	increase	+5%
Bridge Substructure Concrete	(510A000)	increase	+4%
Plant Mix Bituminous Base	(327A005)	decrease	-1%.

Accordingly the base cost per foot was increased, in accordance with Table 22, by eight per cent. The result of this increase is reflected in Table 24.

Table 24 reflects the detailed breakdown of the adjusted base cost per foot obtained in the Sample Calculation Example 1. The adjusted base cost per foot is as follows:

Base Cost per foot:	$388.00	
Adjustment Factor :	+ 8 %	
Increase in Base Cost:	$ 31.04	
Adjusted Base Cost:	$419.04	(108% of Base Cost)

Table 23

Detailed material costs:
base cost per foot sample calculation example 1
based on
project length in feet
Bridge Replacement and Approaches Category

PROJECT LENGTH	BASE COST	MATERIAL	% BASE COST OF MATERIAL	BASE COST/ft OF MATERIAL
1500 ft	$388.00	510C010	10%	$38.80
		513B004	9%	$34.92
		600A000	4%	$15.52
		201A000	4%	$15.52
		210D000	4%	$15.52
		510A000	5%	$19.40
		505C001	3%	$11.64
		610C001	3%	$11.64
		206A000	2%	$ 7.76
		450B000	2%	$ 7.76
		502A000	2%	$ 7.76
		210A000	3%	$11.64
		327A005	2%	$ 7.76
		414A005	2%	$ 7.76
		416A005	2%	$ 7.76
		505C000	1%	$ 3.88
		508A000	1%	$ 3.88
		665J000	1%	$ 3.88
		SUBTOTAL	60%	$232.80
		ALL OTHER	40%	$155.20
		TOTAL	100%	$388.00

Table 24

Detailed material costs:
adjusted base cost sample calculation example 1
based on
project length in feet
Bridge Replacement and Approaches Category

PROJECT LENGTH	BASE COST	MATERIAL	% BASE COST OF MATERIAL	BASE COST/ft OF MATERIAL
1500 ft	$419.04	510C010	10%	$38.80
		513B004	9%	$34.92
		600A000	4%	$15.52
		201A000	4%	$15.52
		210D001	9%	$34.92
		510A000	9%	$34.92
		505C001	3%	$11.64
		610C001	3%	$11.64
		206A000	2%	$ 7.76
		450B000	2%	$ 7.76
		502A000	2%	$ 7.76
		210A000	3%	$11.64
		327A005	1%	$ 3.88
		414A005	2%	$ 7.76
		416A005	2%	$ 7.76
		505C000	1%	$ 3.88
		508A000	1%	$ 3.88
		665J000	1%	$ 3.88
		SUBTOTAL	68%	$263.84
		ALL OTHER	40%	$155.20
		TOTAL	108%	$419.04

AD-A170 931 PRELIMINARY COST ESTIMATING FOR HIGHWAY CONSTRUCTION PROJECTS(U) ARMY MILITARY PERSONNEL CENTER ALEXANDRIA VA A F KAMINSKY 27 AUG 86 2/2

UNCLASSIFIED F/G 13/3 NL

END
DATE
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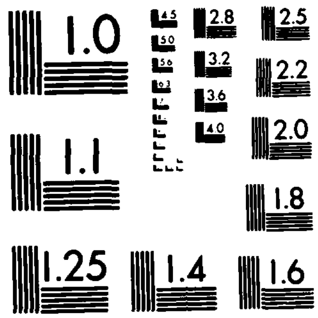
9-86



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Examination of material cost as a percentage of total project cost, Table 16 and Figure 7 the following cost per foot for a project based on the dominant materials and a Bridge Length of 225 feet is shown in Table 25.

In Example 2 of the Sample Calculation the construction base cost per foot of bridge length was adjusted for an increase or decrease in the requirement for the following materials:

Borrow Excavation	(210D000)	increase	+5%
Bridge Substructure Concrete	(510A000)	increase	+4%
Plant Mix Bituminous Base	(327A005)	decrease	-1%

Accordingly the base cost per foot was increased, in accordance with Table 22, by eight per cent. The result of this increase is reflected in Table 26.

Table 26 reflects the detailed breakdown of the adjusted base cost per foot obtained in the Sample Calculation Example 2. The adjusted base cost per foot of bridge length is as follows:

Base Cost per foot:	$3500.00
Adjustment Factor :	+ 8 %
Increase in Base Cost:	$ 280.00
Adjusted Base Cost:	$3780.00 (108% of Base Cost).

Summary

The procedure derived for the Maintenance and Resurfacing category in estimating project cost is applicable to estimating the cost of Bridge Replacement and Approaches projects in the State of Alabama. However,

Table 25

Detailed material costs:
base cost per foot sample calculation example 2
based on
bridge length in feet
Bridge Replacement, and Approaches Category

BRIDGE LENGTH	BASE COST	MATERIAL	% BASE COST OF MATERIAL	BASE COST/ft OF MATERIAL
225 ft	$3,500.00	510C010	10%	$350.00
		513B004	9%	$315.00
		600A000	4%	$140.00
		201A000	4%	$140.00
		210D000	4%	$140.00
		510A000	5%	$175.00
		505C001	3%	$105.00
		610C001	3%	$105.00
		206A000	2%	$ 70.00
		450B000	2%	$ 70.00
		502A000	2%	$ 70.00
		210A000	3%	$105.00
		327A005	2%	$ 70.00
		414A005	2%	$ 70.00
		416A005	2%	$ 70.00
		505C000	1%	$ 35.00
		508A000	1%	$ 35.00
		665J000	1%	$ 35.00
		Subtotal	60%	$2100.00
		All other	40%	$1400.00
		Total	100%	$3500.00

Table 26

Detailed material costs:
adjusted base cost sample calculation example 2
based on
bridge length in feet
Bridge Replacement and Approaches Category

BRIDGE LENGTH	BASE COST	MATERIAL	% BASE COST OF MATERIAL	BASE COST/ft OF MATERIAL
225 ft	$3,780.00	510C010	10%	$350.00
		513B004	9%	$315.00
		600A000	4%	$140.00
		201A000	4%	$140.00
		210D000	9%	$315.00
		510A000	9%	$315.00
		505C001	3%	$105.00
		610C001	3%	$105.00
		206A000	2%	$ 70.00
		450B000	2%	$ 70.00
		502A000	2%	$ 70.00
		210A000	3%	$105.00
		327A005	1%	$ 35.00
		414A005	2%	$ 70.00
		416A005	2%	$ 70.00
		505C000	1%	$ 35.00
		508A000	1%	$ 35.00
		665J000	1%	$ 35.00
		Subtotal	68%	$2380.00
		All other	40%	$1400.00
		Total	108%	$3780.00

several distinct differences apply to the Bridge Replacement and Approaches category. In the earlier procedure developed for maintenance and resurfacing projects, 7 material items were found to dominate project costs. In the bridge replacement category the number of dominant material items increased to 18. However, the bids are still dominated by one-third or fewer of the total pay items, and these items still comprise 90 percent of the total project cost. The number of material items involved in a Bridge Replacement and Approaches project is several times greater than the number contained in a maintenance and resurfacing project. In the bridge replacement category, as in the maintenance and resurfacing category, as the length of the project, or the length of the bridge increases, the cost per foot for construction decreases.

As before, several distinct conclusions can be drawn from the analysis of the Bridge Replacement and Approaches data:

1. The bids are dominated by one-third or fewer of the total pay items, and these items generally comprise 90 percent of the total project cost.
2. The geographic location within the State of Alabama has little effect on the unit price of materials.
3. The cost of bridge replacement is affected by the total project length and the length of the

bridge. The cost per foot decrease as the length of the project or the length of the bridge increases.

4. The dominance of a bid by specific pay items applies to small and large projects alike. No matter how large the project fewer than one-third of the pay items will comprise 90 percent of the project cost.

From the estimating procedure a base cost per foot was determined for both project length and bridge length for the Bridge Replacement and Approaches category. In this procedure, for project length, the interval was established as: 0 - 2000 feet, 2001 feet to 4000 feet, and 4001 feet to 6000 feet. For bridge length the interval was established as: 0 - 300 feet, 301 feet to 600 feet, and 600 to 900 feet. The cost per foot for either bridge length or project length can be adjusted to allow for either an increase or decrease in material quantity when it differs from the normal quantities of a typical project. This procedure relies on determining the mean quantity and standard deviation of quantity for each dominant material. For a typical project the quantity of material and cost are assumed to be constant. This allows for the calculation of cost per foot and quantity per foot to be based on either the total project length or the bridge length. When comparing the differences between an estimate using project length and an

estimate using bridge length, several differences are observed. Since the project length is greater than bridge length, the quantities per foot and cost per foot are less by an approximate ratio of (project length)/(bridge length). Examination of Table 13 and Table 14 shows the construction cost per foot for the first interval of distance in each respective category based on length. In the case of an estimate based on project length the construction cost is $400 per foot. In an estimate based on bridge length the construction cost is $4,148.

A mean quantity of material per foot was calculated for both the project length baseline and bridge length baseline. Subsequently the standard deviation for each material in its respective baseline was determined. This standard deviation of material quantity represents the quantity of material that must either be added to or subtracted from the base quantity of material to allow for variations in material requirements for a project. The coefficient of variation is used to express the standard deviation of material quantity as a percentage of the average material quantity. It is further used to determine the cost added to or subtracted from the base cost per foot when material quantity requirements differ substantially from a typical project. This alteration in base material quantities also produces an altered cost per foot for each material which may be added to or subtracted from the base cost per foot and results in

the new estimated cost per foot. As before, as the amount of material used on a project increases, the unit price of the material decreases in a nonlinear relationship (1).

The procedure developed provides the AHD with the means to estimate preliminary Bridge Replacement and Approaches project costs on a cost per foot basis, based on either total project length or the length of the bridge. With only preliminary material estimates, material quantities may be adjusted for differing site conditions or construction requirements. From this information a base construction cost per foot can be altered and a new base cost calculated. The estimated project cost could then be calculated by multiplying the bridge length or project length by the appropriate base cost. This procedure makes use of historical data which provides the most accurate means of estimating cost.

dBASE III INDEXED FILE
PROJECT #139

RECORD#	ITEM_NO	DESCRIPTION	QUANTITY	ITEM_AMT
49	651B000	TON AGRI LIMESTONE	2	40.00
51	651J000	TON AMMONIUM NITRATE	1	100.00
63	666A000	ACRE PEST CONT TREATMT	12	120.00
50	651C001	TON 8-8-8 FERTILIZER	3	180.00
71	740E000	EA CONES	20	200.00
22	405A000	GAL TACK COAT	217	217.00
25	430B000	TON CIP AGG SURFACE	15	300.00
65	701A008	MI BR YELLOW TRAF STRP	2	400.00
7	214A009	CY STRUCTURE EXCAVA	102	408.00
55	659A001	SY EROSION CNTRL NET	250	437.50
8	214B001	CY FOUND BACKFILL	42	504.00
72	740F002	EA BARRICADE, TY III	2	550.00
59	665F000	EA HAY BALES	150	600.00
68	705A016	EA PAVMT MARKER,CI,T2D	155	620.00
61	665I001	TON TEMP RIPRAP C2	50	750.00
66	701C000	MI BR TEMP TRAF STRIPE	2	750.00
60	665H002	EA ERO CONT CH DAM T1	1	800.00
70	740D000	EA CHANNEL DRUM	20	800.00
56	659A002	SY ERO CONT NET CA	500	875.00
57	665A000	ACRE TEMP SEEDING	3	900.00
58	665B000	ACRE TEMP MULCHING	3	900.00
64	701A004	MI SO WHITE TRAF STRIPE	3	900.00
74	740I002	EA WARNING LIGHT, TC	12	900.00
67	701C001	MI SLD TEMP TRAF STRP	3	1125.00
24	416C005	TON BIT CONC PLNTMIX	50	1200.00
75	999 000	HRS TRAINEE	1500	1200.00
43	630A001	LF STEEL BM GRAIL	100	1250.00
73	740I001	EA WARNING LIGHT, TB	4	1500.00
46	630C010	EA GRAIL ANCHOR	4	2240.00
9	215A000	CY UNCLASS, BR, EXCAV	170	2550.00
69	740B000	SF CONSTRUCTION SIGN	379	2653.00
53	654A001	SY SOLID SODDING	1000	2800.00
39	601A000	EA FURNISH BASE	1	3000.00
41	610D002	SY FILTER BLANKET	1145	4580.00
19	401A000	SYCIP BIT TRTMT A	13146	4601.00
54	656A002	ACRE MULCHING,CA,T1	12	4800.00
38	600A000	LS MOBILIZATION	1	5913.90
52	652A000	ACRE SEEDING MIX A	12	6000.00
18	327D006	TON PLNTMX BIT BASE WID	183	6405.00
44	630C000	EA GRAIL ANCHOR	12	6480.00
42	630A000	LF STEEL BM GRAIL	900	8820.00
20	401A006	SYCIP BIT TRTMT G	12693	8885.10
14	301A191	SYCIP XEL SOIL SBC USL	5452	9268.40

Figure 6

Bridge Replacement and Approaches Category:
dBASE III File Indexed by Ascending Material Cost

48	650B000	CYIP TOPSOIL FR STOCK	3800	9500.00
45	630C003	EA GRAIL ANCHOR T 13	12	9600.00
3	206A001	LS REMOVE BR 697+74.1	1	10000.00
4	206A002	LS REMOVE BR 718+49.7	1	10000.00
37	530A607	LF 54"ROADWAY PIPE	264	13453.44
47	650A000	CYIP TOPSOIL	2500	13750.00
13	301A181	SYCIP SEL SOIL SBC USL	8393	13848.45
12	301A072	SYCIP SEL SOIL SBC USL	8792	14946.40
62	665J000	LF SILT FENCE	5000	16750.00
40	601C001	TON LOOSE RIPRAP C2	1145	17175.00*90%
30	508A000	lb STRUCTURE STEEL	20090	18081.00
28	502C000	LF STEEL PILING	1095	18615.00
27	502A000	lb STEEL REINFORCE	55000	18700.00
21	401A011	SYCIP BIT TRTMT AKG	12502	23753.80
2	206A000	LS REMOVE BR 679+36.5	1	25000.00
15	301A448	SYCIP SEL SOIL SBC USL	13146	29578.50
16	301A502	SYCIP SOIL AGG BC UL	13616	30636.00
26	450B000	SY REINFORCE CEMENT	720	31680.00
36	513B006	LF PRE CONC GIRDER TII	416	41600.00
5	210A000	CYIP UNCLAS EXCAV	32100	48150.00
1	201A000	LS CLEAR & GRUB	1	50500.00
17	327A006	TON PLNTMIX BIT BASE	2354	62969.50
23	416A005	TON BIT CONC WEAR SURF	1909	62997.00
34	510C012	LS REINF CONC SUPRSTR	1	63000.00
11	301A026	SYCIP SEL SOIL SBC USL	43465	65197.50
29	505C001	LF STEEL PILING	4255	80845.00
33	510C001	LS REINF CONC SUPRSTR	1	82000.00
31	510A000	CY BR SUPSTR CONC	533	101270.00
32	510C010	LS REINF CONC SUPRSTR	1	115000.00
6	210D009	CYIP BORROW EXCAV	69950	192362.50
10	235A000	LS DETOUR BR AT 680+3	1	313000.00
35	513B004	LF PRE CONC GIRDER	5786	399234.00

BID $2,100,716.09 75 PAY ITEMS

90% $1,890,644.00 23 PAY ITEMS

Figure 6 (con't)

Bridge Replacement and Approaches Category:
dBASE III File Indexed by Ascending Material Cost

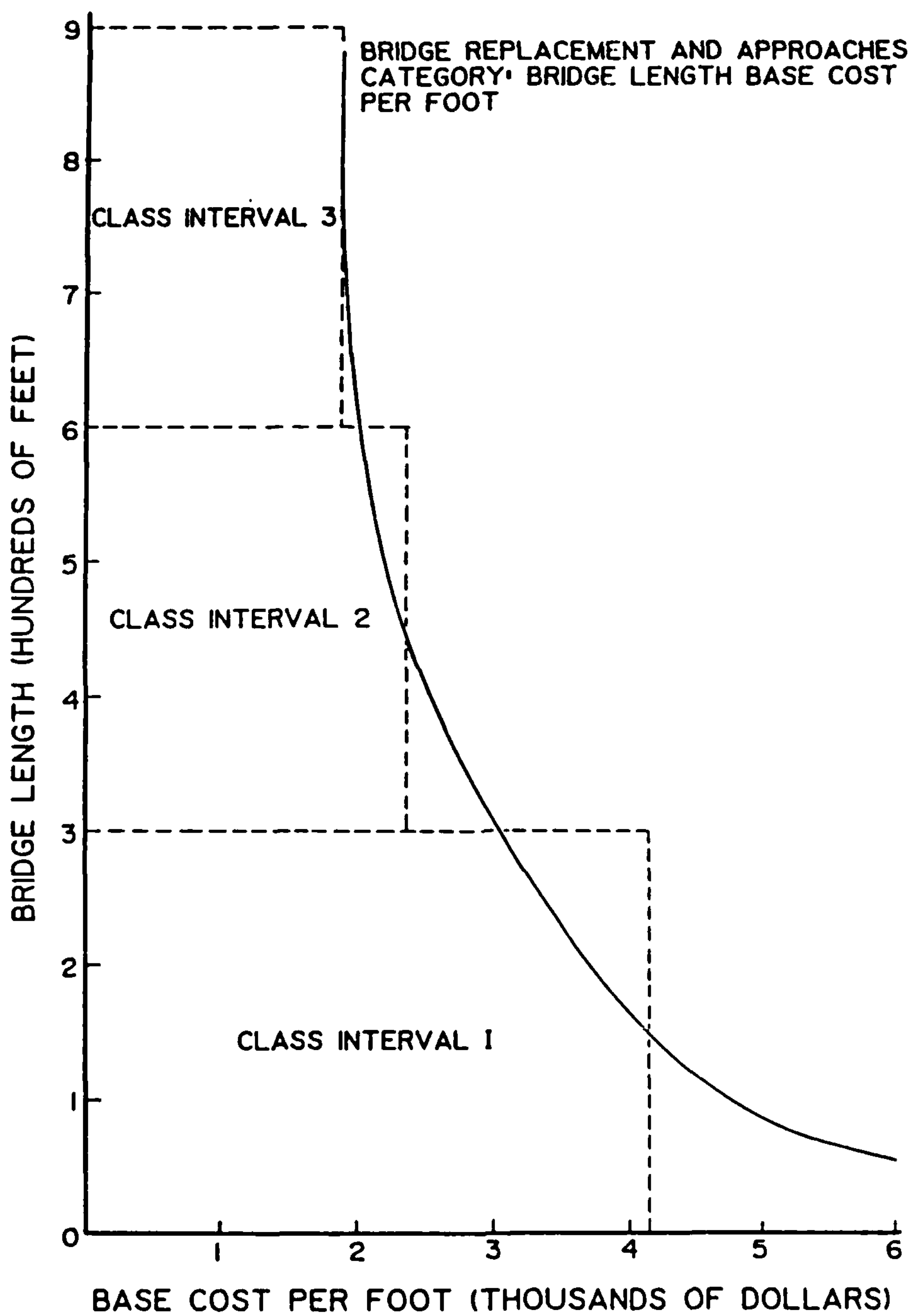


Figure 7

Base Cost Per Foot, Bridge Length:
Bridge Replacement and Approaches Category

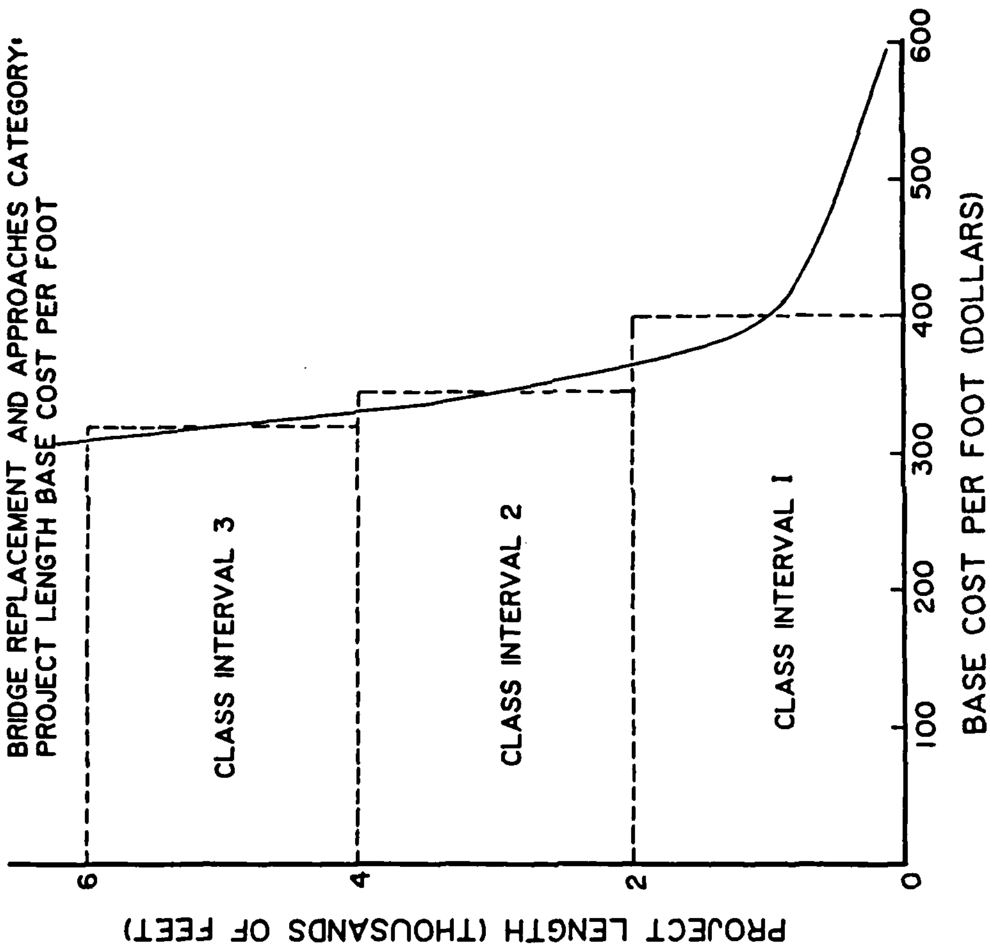


Figure 8

Base Cost Per Foot, Project Length:
Bridge Replacement and Approaches Category

```
SET COLOR TO 7/4,4,4
USE ALHWY5.DBF
SET TALK OFF
INPUT "ENTER ITEM_NO IN DOUBLE QUOTES  :" TO A
AVERAGE QUANTITY/LENGTH FOR ITEM_NO = A .AND. QUANTITY>0 TO AVG
COUNT FOR ITEM_NO = A .AND. COST>0 TO N
GO TOP
S=0
T=0
DO WHILE .NOT. EOF()
IF PROJ_NO>=138.OR.PROJ_NO<=152
IF A=ITEM_NO
IF COST>0
C=QUANTITY/LENGTH
T=T+(C-AVG)*(C-AVG)
S=S+ITEM_AMT
ENDIF
ENDIF
ENDIF
SKIP
ENDDO
?
?"FOR THE ITEM_NO",A
?"THE NUMBER OF RECORDS IN THE FILE IS",N
?"THE AVERAGE VALUE OF THE QUANTITY/MILE IS",AVG
Q=SQRT(T/(N-1))
?"THE VALUE OF THE STANDARD DEVIATION IS",Q
V=Q/AVG
?"THE VALUE OF THE COEF OF VARIATION IS",V
R=S/17574074
?
?"THE TOTAL $ AMOUNT IS",S
?"THE % FOR THE AVG PROJECT IS",R
RETURN
```

Figure 9

dBASE III Command File:
Bridge Replacement and Approaches Category

```
. DO DBASE2A.PRG
ENTER ITEM_NO IN DOUBLE QUOTES:"510C010"
FOR THE ITEM_NO 510C010
THE NUMBER OF RECORDS IN THE FILE IS            14
THE AVERAGE VALUE OF THE QUANTITY/MILE IS        2.658
THE VALUE OF THE STANDARD DEVIATION IS           4.211130
THE VALUE OF THE COEF OF VARIATION IS            1.584574
THE TOTAL $ AMOUNT IS                      1741950.00
THE % FOR THE AVG PROJECT IS                     0.10


. DO DBASE2A.PRG
ENTER ITEM_NO IN DOUBLE QUOTES:"513B004"
FOR THE ITEM_NO 513B004
THE NUMBER OF RECORDS IN THE FILE IS            14
THE AVERAGE VALUE OF THE QUANTITY/MILE IS     5167.069
THE VALUE OF THE STANDARD DEVIATION IS        4739.731388
THE VALUE OF THE COEF OF VARIATION IS            0.917296
THE TOTAL $ AMOUNT IS                      1592938.00
THE % FOR THE AVG PROJECT IS                     0.09
```

Figure 10

Bridge Replacement and Approaches Category:
dBASE III Command File Output

VI. DEVELOPMENT OF COST ESTIMATING PROCEDURE: GRADE, BASE AND DRAIN CATEGORY

Project Category Overview

The third and final category analyzed in the development of the future cost estimating procedure was the Grade, Base and Drain category. This category was represented by 14 projects from 1984. A detailed examination of the projects shows that 10 projects are two-lane projects, 3 projects are four-lane, and one project is a combination of two and four lanes. In development of the cost estimating procedure for the Grade, Base and Drain category, only two-lane projects were considered. The Grade, Base and Drain category for two-lane projects had 10 bids and the database file consisted of 1064 records requiring 82251 bytes of file space. A typical or average Grade, Base and Drain project would have 106 material items, cost $1,350,185, and have a project length of 1.6 miles.

Cost Estimating Procedure Derivation

Following the procedure previously developed for the Maintenance and Resurfacing and Bridge Replacement and Approaches categories and applying the procedure to the Grade, Base and Drain category it is evident that the same

criteria apply and the same method may be used. In the Grade, Base and Drain category 10 two-lane projects from 1984 were used. Examination of the bids indicates that ninety percent of the projects' cost is represented by one-third or less of the pay items. Following the previously developed procedure each project within the database file was INDEXed by material cost. In the database the field material cost was specified as ITEM_AMT. After the indexing procedure each pay item was counted and its cost summed from the bottom of the indexed project bid until 90 percent of the total project cost was achieved as shown in Figure 11. A frequency record was kept based on the number of times each pay item appeared in the group of pay items representing 90 per cent of the project cost. In the 10 bids considered in the Grade, Base and Drain category, the 26 materials listed in Table 27 were found to dominate these projects and the contractors' bids.

The 10 projects used in development of the cost estimating procedure represented all work performed on two lane roads in this category during 1984. The projects were further categorized according to project length. The number of class intervals selected was three. The average cost per mile was determined for each class interval as well as the average cost per mile for all projects. The average cost per mile is displayed in Table 28.

Table 27

Dominant Materials:
Grade, Base and Drain Category
10 total bids

ITEM_NO	DESCRIPTION	FREQUENCY OF OCCURRENCE
201A000	Lump Sum Clearing and Grubbing	10
210A000	Unclassified Excavation (CYIP)	10
210D000	Borrow Excavation (CYIP)	7
214A000	Structure Excavation (CY)	10
214B001	Foundation Backfill (CY)	6
230A000	Roadbed Processing (RDBD STA)	8
301A701	Crushed Agg Base Course (SYCIP)	5
327A005	Plant Mix Bituminous Base (TON)	3
327A006	Plant Mix B Bituminous Base (TON)	4
401A000	Bituminous Treatment A (SYCIP)	5
401A006	Bituminous Treatment G (SYCIP)	6
414A005	Bituminous Conc Binder Layer (TON)	10
416A005	Bituminous Conc Wearing Surface (TON)	10
502A000	Steel Reinforcement (lb)	7
524A000	Culvert Concrete (CY)	3
533A131	30" Storm Sewer (ft)	4
600A000	Lump Sum Mobilization	10
610C001	Loose Rip Rap (TON)	4
614A000	Slope Paving (CY)	6
621C015	Inlet (ea)	5
623B000	Concrete Curb (ft)	4
623C000	Combination Curb & Gutter (ft)	5
650A000	Top Soil (CYIP)	9
650B000	Top Soil Stockpile (CYIP)	6
730C000	Furnish/Install Traf Cntrl Unit	3
740B000	Construction Signs (SF)	5

Table 28

Average Cost per mile:
Grade, Base and Drain Category

#PROJECTS	LENGTH (miles)	AVG $/(MI)	TOTAL LENGTH (miles)	TOTAL COST
6	0 - 2.0	$2,048,980	3.75	$ 7,683,676
3	2.01 - 4.0	$1,540,692	7.96	$12,263,911
1	4.01 - 6.0	$ 348,511	4.13	$ 1,439,349
10		$1,350,185	15.84	$21,386,936

NOTE: Average $ per mile = Total Cost / Total Length (MI) for each interval.

From Table 28 the midpoint of each project interval was determined and the corresponding base cost per mile calculated. These points were graphically connected by as smooth a line as possible to yield the cost curve in Figure 12. The shape of the base cost curve developed for this category differs from the shapes of the base cost curves for the two preceding project categories. This difference in shape can be attributed to such factors as the range of cost and project length for Grade, Base and Drain projects. The cost of a Grade, Base and Drain project ranged from approximately $460,000 to over $5,600,000 and project length varied from slightly less than one-half mile to slightly more than 5.1 miles. As the length of a project increased the corresponding decrease in cost per mile was less pronounced than in the two preceding project categories. The effect of the increased number of pay items in bids for the Grade, Base and Drain category also contributes to the more uniform decrease in cost per mile as the length of the project increases. Figure 12 provides the cost estimator with the means to determine an accurate Base Cost per mile for any project length within a range of values. The cost estimator would estimate the total project length, which are the y axis values, and read to the right to the intersecting value on the cost curve. From the intersecting point read down to the x axis and determine the estimated base cost per mile.

Using a dBASE III command file Figure 13 the following items were calculated for the dominant 26 material items in Table 27:

- Average quantity per mile;
- Standard deviation of the quantity per mile:
- Coefficient of variation of the quantity per mile;
- Total dollar amount for a material for all bids;
- Material cost as a percentage of the average project cost.

Table 29 is a listing of the values obtained when the dBASE III command file Figure 14 was executed. In Table 29, the average quantity of material per mile required for a typical project, for the 26 dominant materials, was calculated based on total project length. Since, these 26 materials comprise the major cost of the project, their actual percentage of total project cost was determined.

Table 29

Average quantity of material
and
Material cost as a percentage of total project cost
Grade, Base and Drain Category

MATERIAL	AVG QUAN/mi	STD DEV QUAN/mi	CV	% OF TOTAL PROJ COST
210A000	95771 CYIP	154965 CYIP	1.618	8
414A005	3945 TON	3489 TON	0.884	6
327A006	3958 TON	3061 TON	0.773	4
416A005	2382 TON	1632 TON	0.685	4
201A000	$47,159.00	$37,963.00	0.685	3
210D000	19378 CYIP	24505 CYIP	1.265	3
524A000	919 CY	733 CY	0.798	3
600A000	$46,433.00	$37,379.00	0.685	3
301A701	36580 SYCIP	15122 SYCIP	0.413	2
327A005	3128 TON	1271 TON	0.406	2
502A000	91712 lb	118506 LB	1.292	2
614A000	113 CY	190 CY	1.675	1
214A000	4187 CY	4015 CY	0.959	1
230A000	67 STA	31 STA	0.459	1
401A006	23732 SYCIP	15807 SYCIP	0.666	1
610C001	1042 TON	1319 TON	1.265	1
621C015	21 ea	6 ea	0.264	1
623B000	2643 ft	3844 ft	1.454	1
623C000	6492 ft	4034 ft	0.621	1
650A000	6007 CYIP	4934 CYIP	0.821	1
650B000	2813 CYIP	2741 CYIP	0.974	1
730C000	$28,445.00	$12,800.00	0.450	1
214B001	670 CY	692 CY	1.033	0.5
401A000	29103 SYCIP	16149 SYCIP	0.555	0.5
533A131	662 ft	386 ft	0.584	0.5
740B000	840 SF	516 SF	0.614	0.5

NOTE: Items 201A000, 600A000 and 730C000 are traditionally bid as a lump sum item. In order to make a meaningful estimate of the cost of these items it is necessary to convert them to a cost per mile basis since their unit of measurement is monetary. The average quantity per mile may also be represented by the quantity Dollars per mile. This quantity is determined by dividing Material Cost by Length. Tables 30 and 31 provide the cost estimator with a meaningful measure of these item costs based on calculating the project cost using project length as the estimating baseline.

Once the base cost per mile or base material requirement per mile for each dominant material has been determined, an adjustment factor must be developed. This adjustment factor would allow the cost estimator to adjust the material quantity requirement for each dominant material when differing conditions for a project exist from what is considered a typical project. This adjustment factor allows the estimator to increase or decrease his base cost per mile based on material requirements.

The base cost per mile may be adjusted when it is known that the material quantities used per mile are substantially greater or substantially less than normal. Table 32 indicates three levels of anticipated material quantity usage: (1) average - used on a typical project, (2) upper limit (UL) - used on a project requiring more material than a typical project, and (3) lower limit (LL) - used on a project requiring less material than a typical project. For each of the 26 dominant materials an adjustment factor equal to one standard deviation of material quantity was calculated. In an upper limit material quantity requirement, the quantity used is equal to the typical quantity plus one standard deviation. In a lower limit material quantity requirement, the quantity used is equal to the typical quantity minus one standard deviation or zero if a negative requirement occurs. One standard deviation of material quantity was selected as an initial material

Table 30

Average lump sum material cost per project:
Grade, Base and Drain Category

MATERIAL	# PROJECTS	COST	AVG COST/PROJECT	CV
201A000	10	$ 747,000.00	$74,700.00	0.685
600A000	10	$ 735,500.00	$73,550.00	0.685
730C000	3	$ 129,710.00	$43,236.67	0.516

Table 31

Average lump sum material cost per mile:
Grade, Base and Drain Category

MATERIAL	AVERAGE LUMP SUM UNITS/MI	AVG $/MI	PROJECT LENGTH (MI)	STD DEV (MI)	DOLLARS per STD DEV
201A000	1.174	$47,159.00	15.84	0.805	$37,963.00
600A000	1.174	$46,433.00	15.84	0.805	$37,379.00
730C000	0.872	$28,445.00	4.56	0.450	$12,800.00

NOTE: The calculation of the quantity Dollars per Standard Deviation is based on the mathematical relationship for calculating the coefficient of variation (CV), where:

$$CV = (\text{Standard Deviation}) / (\text{Mean})$$

Since, the coefficient of variation is known and the mean for a lump sum material item can be expressed in terms of Dollars the Standard Deviation, in Dollars per mile, can be calculated. This provides the cost estimator with a meaningful measure of lump sum costs.

quantity adjustment to represent the UL and LL values of material quantity. The UL and LL material quantity values may be increased or decreased by the estimator to improve accuracy.

A dBASE III command file was used to calculate the values of the coefficient of variation and material cost as a percentage of total project cost for each dominant material. These values were included in Table 29. Extracting these values from Table 29 a base cost adjustment guide was developed. The percentage of the base cost per mile that each dominant material contributes is reflected in the following relationship:

% of Base Cost = Coefficient of Variation X % Item Cost as a % of Total Project Cost;

where, coefficient of variation (CV) = (Standard Deviation) / (Average Quantity per mile)

For example, 414A005 : (Values from Table 29)

CV = 3489 / 3945
= 0.884

% of Total Cost of item 414A005 for all projects :

where, Total Cost all projects = \$21,386,935.81 (Table 28)
Total cost item 414A005 = \$ 1,303,314.05 (Figure 14)

% = \$1,303,314.05 / \$21,386,935.81
= 0.061
= 6 %

Adjustment Factor = CV X % Item Cost
= 0.884 X 6%
= 5%

As a result of similar calculations for all 26 dominant

Table 32

Estimated material requirement per mile:
Grade, Base and Drain Category

MATERIAL	AVG QUAN/MI	UPPER LIMIT (UL) QUANTITY/MI	LOWER LIMIT (LL) QUANTITY/MI
210A000	95771 CYIP	250736 CYIP	0
414A005	3945 TON	7434 TON	456 TON
201A000	$47,159.00	$85,122.00	$9,196.00
210D000	19378 CYIP	43883 CYIP	0
524A000	919 CY	1652 CY	186 CY
600A000	$46,433.00	$83,812.00	$9,054.00
327A006	3958 TON	7019 TON	897 TON
416A005	2382 TON	4014 TON	750 TON
301A701	36580 SYCIP	51702 SYCIP	21458 SYCIP
327A005	3128 TON	4399 TON	1857 TON
502A000	91712 lb	210218 lb	0
614A000	113 CY	303 CY	0
214A000	4187 CY	8202 CY	172 CY
230A000	67 STA	98 STA	36 STA
401A006	23732 SYCIP	39539 SYCIP	7925 SYCIP
610C001	1042 TON	2361 TON	0
623C000	6492 ft	10526 ft	2458 ft
650A000	6007 CYIP	10941 CYIP	1073 CYIP
650B000	2813 CYIP	5554 CYIP	72 CYIP
730C000	$28,485.00	$41,285.00	$15,685.00
214B001	670 CY	1362 CY	0
401A000	29103 SYCIP	45256 SYCIP	12954 SYCIP
533A131	662 ft	1048 ft	276 ft
621C015	21 ea	27 ea	15 ea
623B000	2643 ft	6487 ft	0
740B000	840 SF	1356 SF	324 SF

material items the following estimating guide was developed as shown in Table 33.

Sample Calculation

In order to perform a sample estimating calculation Table 33 and Figure 12 are used. Figure 12 is used to determine the base cost per mile based on an estimated project length. Table 33 is used as a cost adjustment guide for material quantity variation.

EXAMPLE: How much should a proposed Grade, Base and Drain project with a total project length of 3 miles cost if it is expected that the project will use the following material items that differ significantly from a typical project?

210A000	Unclassified Excavation	- greater than average
214A000	Structure Excavation	- greater than average
414A005	Bit Concrete Binder Layer	- greater than average
201A000	Clearing and Grubbing	- less than average

SOLUTION:

1. Given: Project Length 3 miles.

   From Figure 12 - Determine Base Cost per mile.

   Base Cost per mile = $1,540,000.00 (Typical Project)

2. Cost of a typical Grade, Base and Drain project 3 miles in length.

   Typical Cost = Project Length X Base Cost per mile
   = 3 X $1,540,000.00
   = $4,620,000.00

3. How much must this base cost estimate be adjusted to allow for greater than average unclassified excavation, structure excavation and bituminous concrete binder layer use, and less than average use of lump sum clearing and grubbing?

Table 33

Base cost adjustment guide:
Grade, Base and Drain Category

Alter Base Cost by + or - percentage stated below.

MATERIAL UNIT	PROJECT LENGTH (miles) 0 - 2.0	PROJECT LENGTH (miles) 2.01 - 4.0	PROJECT LENGTH (miles) 4.01 - 6.0
210A000	13%	13%	13%
414A005	5%	5%	5%
210D000	4%	4%	4%
327A006	3%	3%	3%
416A005	3%	3%	3%
502A000	3%	3%	3%
524A000	2%	2%	2%
201A000	2%	2%	2%
600A000	2%	2%	2%
614A000	2%	2%	2%
301A701	1%	1%	1%
327A005	1%	1%	1%
214A000	1%	1%	1%
401A006	1%	1%	1%
610C001	1%	1%	1%
623B000	1%	1%	1%
623C000	1%	1%	1%
650A000	1%	1%	1%
650B000	1%	1%	1%
230A000	0.5%	0.5%	0.5%
730C000	0.5%	0.5%	0.5%
214B001	0.5%	0.5%	0.5%
401A000	0.5%	0.5%	0.5%
533A131	0.5%	0.5%	0.5%
621C015	0.5%	0.5%	0.5%
740B000	0.5%	0.5%	0.5%

From Table 33 - Adjustment Factors

Unclassified Excavation	(210A000)	=	increase +13%
Structure Excavation	(214A000)	=	increase + 1%
Bit Concrete Binder Layer	(414A005)	=	increase + 5%
Clearing and Grubbing	(201A000)	=	decrease - 2%
Total Adjustment		=	increase +17%

4. Cost of the project adjusted for material quantity variation.

New Cost = Typical Cost + Material Adjustment Cost
= \$4,620,000.00 + (17% X \$4,620,000.00)
= \$5,405,400.00

Summary

The previously derived procedure for the Maintenance and Resurfacing and Bridge Replacement and Approaches categories in estimating future project cost is applicable to estimating the cost of Grade, Base and Drain projects in the State of Alabama. However, several differences exist in the Grade, Base and Drain category. In examining the Maintenance and Resurfacing category, 7 pay items were found to dominate project costs. These items were primarily asphaltic construction materials. In the Bridge Replacement and Approaches category, the number of dominant material items increased to 18. The composition of these dominant materials broadened to include a wider variety of structural material and excavation costs. In the final category examined, Grade, Base and Drain the number of dominant materials increased to 26. Again, the dominant materials included a wider variety of construction materials, excavation and specialized construction operations. The

average number of material items has increased from the Maintenance and Resurfacing category to the Bridge Replacement and Approaches category reaching its highest average number in the Grade, Base and Drain category. However, the bids still remain dominated by one-third or fewer of the total pay items, and these material items still comprise 90 percent of the total project cost.

In the Grade, Base and Drain project category, as in the Maintenance and Resurfacing and Bridge Replacement and Approaches categories, as the length of the project increases, the cost per mile for construction decreases.

Several distinct conclusions can be drawn from the analysis of the Grade, Base and Drain category data:

1. The bids are dominated by one-third or fewer of the pay items, and these pay items generally comprise 90 percent of the total project cost.
2. The geographic location within the State of Alabama has little effect on the unit price of materials.
3. The cost of Grade, Base and Drain projects is affected by the length of the project. The cost per mile decreases as the length of the project increases.
4. The dominance of a bid by specific pay items applies to large and small projects alike. No

matter how large the project fewer than one-third of the pay item comprise 90 percent of the project cost.

From the cost estimating procedure a base cost per mile was determined for the Grade, Base and Drain category. In this procedure, the interval was established as 0 - 2.0 miles, 2.01 miles - 4.0 miles, and 4.01 miles - 6.0 miles. The construction cost per mile can be adjusted to allow for either an increase or decrease in material quantity when requirements differ significantly from the normal quantities of a typical project. This procedure relies on determining the mean quantity and standard deviation of quantity for each dominant material to establish a baseline and adjustment factors. The standard deviation of material quantity represents the quantity of material that must either be added to or subtracted from the mean quantity to allow for variations in material requirements for a project. The coefficient of variation is used to express the standard deviation of material quantity as a percentage of the average material quantity. It is further used to determine the cost added to or subtracted from the base cost per mile when material quantity requirements differ substantially from a typical project. For a typical project the quantity of material and cost are assumed to be constant. This alteration of mean or typical material quantities also produces a similarly altered cost per mile which increases

or decreases base cost by the same percentage tnat material quantities are altered. This alteration of base cost results in the new estimated cost per mile which reflects job specific requirements. As before, as the amount of material used on a project increases, the unit price of the material decreases in a nonlinear relationship (1).

The procedure developed provides the AHD with the means to estimate future Grade, Base and Drain project costs on a cost per mile basis with only preliminary material quantity estimates. Material quantities may be adjusted for differing site conditions or construction requirements. From this information, a base construction cost per mile can be altered and a new base cost calculated. The estimated project cost could then be calculated by multiplying the project length by the appropriate base cost. This procedure makes use of historical data which provides the most accurate means of estimating costs.

dBASE III INDEX FILE
PROJECT #118

RECORD#	ITEM_NO	DESCRIPTION	QUANTITY	ITEM_AMT
80	998A000	LS CONSTRUC FUEL	1	0.00
66	705A004	EA PAVE MARKERS	4	14.00
42	651B000	TON AGRICULTURAL LIME	3	30.00
64	705A000	EA PAVE MARKERS	39	124.80
52	666A000	ACRE PEST CONTROL	15	150.00
44	651J000	TON AMMONIUM NITRATE	1	180.00
58	701B002	LF DOTTED TRAF STRIPE	680	204.00
70	709A001	EA MILE POST	5	250.00
38	621D019	EA INLET UNITS	1	275.00
56	701A012	MI SOLID YELLOW STRIPE	1	300.00
62	701D001	MI REMOVE TRAFF STRIPE	1	350.00
60	701C001	MI TEMP TRAF STRIPE	2	400.00
61	701D000	MI REMOVE TRAFF STRIPE	1	430.00
28	535A000	LF 15" SIDEDRAIN PIPE	44	440.00
75	740D000	EA CHANNELIZING DRUMS	18	450.00
43	651C001	TON 8-8-8 FERTILIZER	4	500.00
69	707B003	EA HAZARD MARKER	2	500.00
35	621A000	EA JUNCTION BOXES	1	600.00
53	701A002	MI BROKEN WHITE TRAF STRP	1	600.00
4	214A000	CY STRUCTURE EXCAV	150	750.00
59	701C000	MI TEMP TRAF STRIPE	5	850.00
48	659A001	SY EROSION CONTROL	500	900.00
5	214B001	CY FOUNDATION BACKFILL	68	1020.00
24	416D005	TON BIT CONC PLANT MIX	38	1026.00
68	705A006	EA PAVMT MARKERS	325	1105.00
76	740F002	EA BARRICADES, TY III	4	1400.00
65	705A001	EA PAVMT MARKERS	445	1424.00
25	430B020	TON CIP AGG SURFACING	200	1500.00
51	665J000	LF SILT FENCE	500	1500.00
50	665F000	EA HAY BALES	500	1575.00
26	530A451	LF 18" RDWY PIPE	123	1599.00
67	705A005	EA PAVMT MARKERS	480	1632.00
37	621C020	EA INLETS	2	1800.00
49	659A002	SY EROSION CONTROL	1000	1800.00
55	701A010	MI BRKN YELLOW STRIPE	3	1800.00
21	414D005	TON BIT CONC PLANT MIX	74	1850.00
29	535A001	LF 18" SIDEDRAIN PIPE	172	2021.00
39	623B000	LF CONCRETE CURB	104	2080.00
40	623B001	CONCRETE CURB	112	2240.00
78	740I002	EA WARNING LIGHT TY C	8	2800.00
46	654A001	SY SOLID SODDING	1000	2850.00
31	601A000	EA FURNISHING BASE	1	3000.00

Figure 11

Grade Base and Drain Category:
dBASE III File Indexed by Ascending Material Cost

33	606A000	LF 6" UNDERDRAIN PIPE	1000	3000.00
54	701A004	MI WHITE TRAF STRIPE	10	3000.00
13	327D006	TON PLANT MIX BIT BASE	132	3300.00
73	710B001	LF RDWY SIGN POST	883	3487.85
20	414C005	TON BIT CONCRETE	200	3500.00
72	710A090	SF CL 4 FLAT SIGN	191	4202.00
36	621C019	EA INLETS	3	4500.00
79	741A000	EA PORT SEQU ARROW	1	4500.00
71	710A030	SF CL 4, FLAT SIGN	262	4716.00
34	614A000	CY SLOPE PAVING	24	4800.00
27	530B200	LF 17" SPAN RDWY PIPE	293	4834.50
23	416C005	BIT CONC PLANT MIX	200	5400.00
57	701A014	MI SOLID YELLOW STRIPE	5	5500.00
47	656A002	ACRE MULCH	15	5700.00
74	740B000	SF CONSTRUC SIGNS	1187	5935.00
45	652A001	ACRES SEEDING	15	6150.00
63	703A002	SF TRAFF CNTRL MARKGS	4593	6430.20
18	410A001	EA NUCL ASPH GAUGE	1	6500.00
2	210A000	CYIP UNCLASS EXCAV	6200	8060.00
17	405A000	GAL TACK COAT	10710	8568.00
41	650B000	CYIP TOPSOIL	7000	16800.00*90%
14	401A000	SYCIP BIT TREATMENT A	85560	17112.00
32	605B002	EA UNDERDRAIN OUTLET	146	18250.00
30	600A000	LS MOBILIZATION	1	20000.00
77	740I001	EA WARNING LIGHT, TY B	20	20000.00
1	201A000	LS CLEAR & GRUB	1	24000.00
15	401A006	SYCIP BIT TREATMENT G	79500	31800.00
10	301B002	CYCIP SEL S/SBC	8150	36675.00
3	210D000	CYIP BORROW EXCAVATION	27900	41850.00
16	401A011	SYCIP BIT TREATMENT	46675	56010.00
11	315A000	SYCIP DRAIN MATERIAL	73075	73075.00
9	301A861	SYCIP CRUSH AGG	58955	79589.25
6	230A000	ROADBED PROCESSING	237	106650.00
22	416A005	TON BIT CONC WEAR	4240	114268.00
7	301A035	SYCIP SEL SOIL /SBC	159120	127296.00
19	414A005	TON BIT CONC BINDER	7330	128275.00
8	301A700	SYCIP CRUCH AGG	85560	171120.00
12	327A006	TON PLANT MIX BIT BASE	12010	210175.00

BID $1,439,348.60 80 PAY ITEMS

90% $1,295.414.00 18 PAY ITEMS

Figure 11 (con't)

Grade, Base and Drain Category:
dBASE III File Indexed by Ascending Material Cost

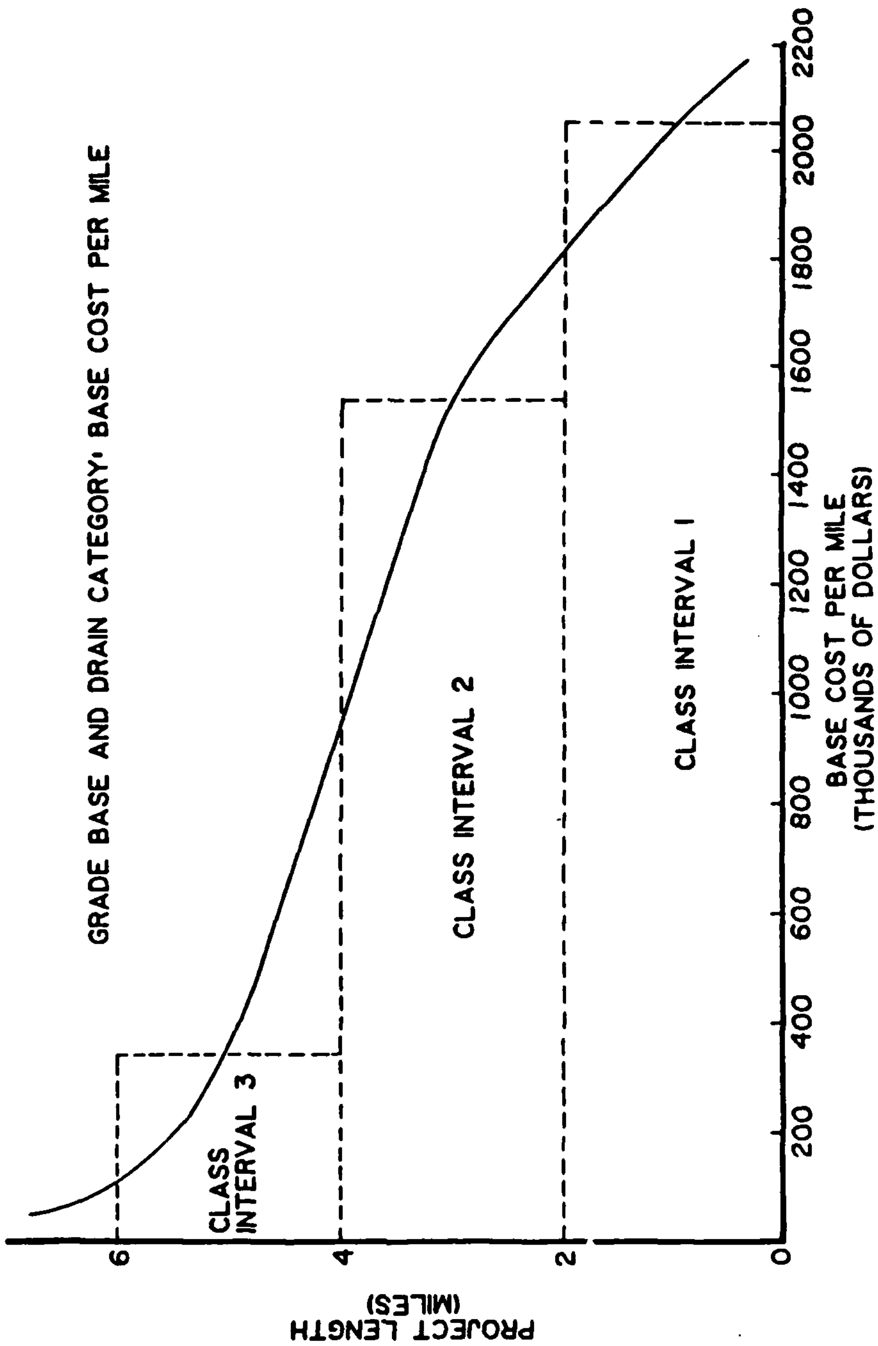


Figure 12

Base Cost Per Mile:
Grade, Base and Drain Category

```
SET COLOR TO 7/4,4,4
USE ALHWY2C.DBF
SET TALK OFF
INPUT "ENTER ITEM_NO IN DOUBLE QUOTES  :" TO A
AVERAGE QUANTITY/LENGTH FOR ITEM_NO = A .AND. QUANTITY>0 TO AVG
COUNT FOR ITEM_NO = A .AND. COST>0 TO N
GO TOP
S=0
T=0
DO WHILE .NOT. EOF()
IF PROJ_NO>=109.OR.PROJ_NO<=122
IF A=ITEM_NO
IF COST>0
C=QUANTITY/LENGTH
T=T+(C-AVG)*(C-AVG)
S=S+ITEM_AMT
ENDIF
ENDIF
ENDIF
SKIP
ENDDO
?
?"FOR THE ITEM_NO",A
?"THE NUMBER OF RECORDS IN THE FILE IS",N
?"THE AVERAGE VALUE OF THE QUANTITY/MILE IS",AVG
Q=SQRT(T/(N-1))
?"THE VALUE OF THE STANDARD DEVIATION IS",Q
V=Q/AVG
?"THE VALUE OF THE COEF OF VARIATION IS",V
R=S/21386936
?
?"THE TOTAL $ AMOUNT IS",S
?"THE % FOR THE AVG PROJECT IS",R
RETURN
```

Figure 13

dBASE III Command File:
Grade, Base and Drain Category

```
.DO DBASE4A.PRG
ENTER ITEM_NO IN DOUBLE QUOTES: "210A000"
FOR THE ITEM_NO 210A000
THE NUMBER OF RECORDS IN THE FILE IS                10
THE AVERAGE VALUE OF THE QUANTITY/MILE IS        95771.443
THE VALUE OF THE STANDARD DEVIATION IS          154965.113985
THE VALUE OF THE COEF OF VARIATION IS                1.618072
THE TOTAL $ AMOUNT IS                          1754076.92
THE % FOR THE AVG PROJECT IS                         0.08


.DO DBASE4A.PRG
ENTER ITEM_NO IN DOUBLE QUOTES: "414A005"
FOR THE ITEM_NO 414A005
THE NUMBER OF RECORDS IN THE FILE IS                10
THE AVERAGE VALUE OF THE QUANTITY/MILE IS         3944.957
THE VALUE OF THE STANDARD DEVIATION IS            3489.262367
THE VALUE OF THE COEF OF VARIATION IS                0.884487
THE TOTAL $ AMOUNT IS                          1303314.05
THE % FOR THE AVG PROJECT IS                         0.06
```

Figure 14

dBASE III Command File Output:
Grade, Base and Drain Category

VII. CONCLUSIONS

The ability to estimate future highway construction cost is a very important factor in the development of annual budgets. Many decisions in the process of design, resource allocation, and budgeting are dependent on reliable determination of future costs. It is a well known fact that the time span from conceptual design of a construction project to the actual performance can often exceed three or four years. Therefore, it is essential to develop a procedure which will enable estimators and government officials participating in the budget development process to accurately estimate future construction costs.

From this research undertaken for the State of Alabama Highway Department, the analysis of historical project bid data led to the development of a simple procedure for estimating preliminary construction costs. The analysis of large amounts of data was simplified through the use of the software dBASE III and an IBM PC-AT microcomputer. The powerful commands of dBASE III and the computing capabilities of the IBM PC-AT microcomputer facilitated the examination of project database files for trends within the database files for trends within the database file and relationships between database fields.

On the basis of the development of the cost estimating procedure, the following conclusions can be made:

1. Project bids are dominated by one-third or less of the total pay items in the bid. These pay items are referred to as dominant materials.
2. Ninety percent of the project cost is represented by the dominant materials.
3. The dominance of a bid by specific pay items applies to large and small projects alike.
4. The cost of construction, per foot or mile, is affected by project length. As the length of a project increases, the cost of construction per unit of linear measure decreases.
5. The geographic location of a project within the State of Alabama has a negligible effect on the cost estimating procedure.
6. The application of the preliminary cost estimating procedure to three distinctly different types of construction projects examined in this research confirms its usefulness. The preliminary cost estimating procedure developed for the AHD is workable and can be applied to other categories of highway construction.

The preliminary cost estimating procedure developed in this research has the following distinct advantages over other cost estimating methods.

1. The procedure does not require the use of statistical analysis software or require the user to interpret the results obtained.
2. The cost estimator does not have to be knowledgeable in interpreting data and formulating a linear or multiple regression model.
3. This procedure requires only a microcomputer and database management software to analyze project bid data and, therefore, is a relatively low-cost alternative to mainframe computer systems.
4. The microcomputer is a dedicated piece of equipment, and the cost estimator does not have to compete with others for its use.
5. The information provided by the microcomputer is timely and presented in a usable format to the cost estimator.

Through the use of a microcomputer and database management software, a cost estimator can take advantage of user friendly technology. The software dBASE III and the IBM PC-AT microcomputer used in this research project played a key role in data analysis and the management of a significant amount of bid data. The ease and speed of database access is a most noteworthy capability of the microcomputer and software. With a little dedication to learning the capabilities of the dBASE III software, a cost

estimator can greatly improve the accuracy of estimating future costs. The future cost estimating procedure developed for the State of Alabama Highway Department can be a beneficial tool in developing future budgets.

BIBLIOGRAPHY

1. Allen, Dennis, "Introducing the IBM PC-AT," Popular Computing, Volume 4, Number 2, December 1984.

2. Badgett, Tom, "Compaq Deskpro Versus IBM PC-AT," Creative Computing, Volume 11, Number 5, May 1985.

3. Blank, Leland, Statistical Procedures for Engineering, Management and Science, McGraw-Hill, Inc., New York, 1980.

4. Castro, Luis, Jay Hanson, and Tom Rettig. Advanced Programmers Guide Featuring dBASE II and dBASE III, Ashton-Tate, Inc., Culver City, California, 1985.

5. Chou, George Tsu-der, dBASE III Handbook, Que Corporation, Indianapolis, 1985.

6. Daniel, Wayne W. and James C. Terrell. Business Statistics: Basic Concepts and Methodology, 2nd Edition, Houghton-Mifflin Company, Boston, 1979.

7. Furst, Al, "IBM Prevails After Personal Computer Shakeout," High Technology, Volume 5, Number 4, April 1985.

8. Garrett, T., "Linear Regression Analysis of Alabama Highway Department Cost Data," A Thesis Submitted to the Graduate Faculty of Auburn University in Partial Fulfillment of the Requirements for the Degree of Master of Science, Auburn, Alabama, December 12, 1985.

9. Herbsman, Zohar, "Long Range Forecasting Highway Construction Costs," Journal of Construction Engineering and Management, Volume 109, Number 4, December 1983.

10. Hines, William W. and Douglas C. Montgomery. Probability and Statistics in Engineering and Management Science, 2nd Edition, John Wiley and Sons, New York, 1980.

11. Johnson, Robert, Elementary Statistics, 2nd Edition, Duxbury Press, North Scituate, Massachusetts, 1976.

12. Kaminsky, Kurt D. and William D. Ledbetter. "The Evolution of the Microcomputer and its Application in Project Management," Accepted for publication in The Project Management Journal, 1986.

13. Patterson, Scott, "Putting Unix to Task," PC Products, Volume III, Number 3, March 1986.

14. Rosch, Winn L., "Supermicros: Leaving the IBM PC in the Dust," PC Week, Volume 2, Number 15, April 16, 1985.

15. Sanders, Donald H., Computers Today, McGraw-Hill, New York, 1983.

16. Sanders, Donald H., Computers Today, 2nd Edition, McGraw-Hill, New York, 1985.

17. State of Alabama Highway Department, Seventy-Third Annual Report, Montgomery, Alabama, January 1985.

18. State of Alabama Highway Department, Standard Specifications for Highway Construction, 1985 Edition, Montgomery, Alabama, 1985.

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